Museum Victoria
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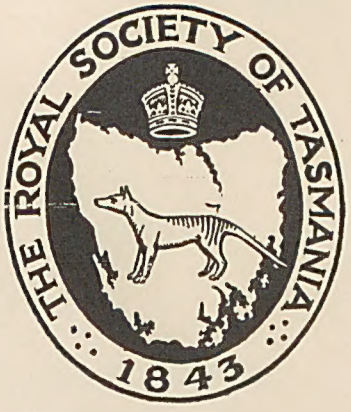
PAPERS AND PROCEEDINGS

OF

The Royal Society of Tasmania

Volume 90



Edited by William Bryden

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1956.

PAPERS AND PROCEEDINGS

OF

The Royal Society

of Tasmania

Volume 30

Royal Society of Tasmania

Volume 90

Annual Report

AND

Proceedings

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The Royal Society of Tasmania

Volume 90

Patron:

Her Majesty the Queen

President:

The Rt. Hon. Sir Ronald Cross, K.C.M.G., K.C.V.O.

Vice-Presidents:

F. C. Wolfhagen, LL.B., till April 1957
W. E. L. H. Crowther, C.B.E., D.S.O., M.B., B.S., F.R.A.C.P., 1956, 1957

Council:

T. Hytten, C.M.G., M.A., 1956, 1957, 1958
C. Bisdee, 1956, 1957, 1958
D. Martin, D.Sc., 1956, 1957
W. V. Teniswood, M.A., Ph.D., 1956, 1957
S. W. Carey, D.Sc., 1956
L. W. Miller, M.Agric.Sc., F.R.E.S., 1956

Hon. Secretary and Librarian:

W. Bryden, M.Sc., Ph.D., F.R.S. (Edin.)

Hon. Treasurer:

G. E. A. Hale, B.Sc.

Hon. Auditor:

A. M. Hewer

Standing Committee:

Dr. D. Martin, Dr. W. V. Teniswood, Mr. L. W. Miller and the Hon. Secretary

Royal Society of Tasmania

Annual Report, 1955

The Annual Meeting was held in the Society's Room, Tasmanian Museum, on 1st March, 1955.

The President, His Excellency the Governor (Sir Ronald Cross), presided.

The following Office-bearers were elected:—

Vice-President: Under the Society's Rules Mr. S. Angel retired from the office of Vice-President and Mr. F. C. Wolfhagen was appointed in his place (retiring 1957).

Hon. Secretary and Librarian: Dr. W. Bryden.

Hon. Treasurer: Mr. G. E. Hale.

Hon. Auditor: Mr. A. M. Hewer.

Council: Under Rule 21 Professor H. N. Barber and Mr. I. G. Anderson retired as members of the Council and Dr. D. Martin and Dr. W. V. Teniswood were elected for a period of three years. Dr. W. L. Crowther was elected for one year in place of Mr. F. C. Wolfhagen, who was appointed a Vice-President.

The names of the full Council for 1955 are given on the previous page.

The Council made the following appointments at its first meeting:—

Standing Committee: Mr. J. W. C. Wyett, Dr. D. Martin, Dr. W. V. Teniswood and the Hon. Secretary.

Board of Trustees of the Tasmanian Museum and Board of Trustees of the Botanical Gardens:

Tasmanian Museum: Professor A. Burn and Dr. C. Loftus-Hills.

Botanical Gardens: Mr. S. Angel.

Representative to the Library Association: Dr. W. Bryden.

In addition to the above, Mr. E. R. Pretyman has continued to represent the Society on the Nomenclature Board.

Meetings: Nine ordinary meetings and one special meeting were held during the year, when the following lectures were given:—

March: "The first phase of the Economic War, Sept. 1939-May 1940," by the President, His Excellency the Governor, Sir Ronald Cross.

April: "Some Observations on the potential for increased primary production in Australia," by Sir Ian Clunies-Ross, Chairman, C.S.I.R.O.

May: "Seals, Sea-lions and Walruses," by Mr. J. L. Davies, University of Tasmania.

June: "A Scientist in America," by Professor H. N. Barber, University of Tasmania.

July: "Radio Astronomy," by Dr. Grote Reber, Research Corporation, New York.

August: "Desert Ecology," by Professor Went, Californian Institute of Technology, Pasadena, U.S.A.

September: "Glimpses of the Philippines," by Mr. C. A. Holland, Department of Agriculture, Hobart.

Special Meeting: in association with the Australian Chemical Institute—"Chromatography", by Dr. R. L. M. Synge, F.R.S.

October: "Development of Tasmanian Railways in the first great economic depression 1860-1875," by Mr. W. A. Townsley, University of Tasmania.

November: "Rabbit Control in Tasmania, with special reference to the Compound 1080," by Mr. G. K. Meldrum, Department of Agriculture, Hobart.

Library: During the year 440 volumes were added to the Library in addition to a number of reports and pamphlets from British and Foreign Institutions and learned Societies. The number of institutions on the exchange list is now 303. The Library now consists of 30,510 volumes.

Membership: The Society consists of the following members:—

Honorary Members		2
Corresponding Members		1
Ordinary Members:		
Class A	271	
Class B	168	
		439
Life Members		31
Associate Members		18
TOTAL		491

During the year 33 names were removed from the list of Members owing to deaths, resignations, &c., and 51 new members were elected.

Deaths: The Council regrets having to record the deaths of the following members: Mrs. A. Dowling, Mr. F. X. de Bavay, Mr. F. W. Needham, Mr. D. M. Urquhart.

During the year the Council considered the whole question of membership of the Society. It was felt that many people in Tasmania who would enjoy the privilege of Royal Society membership were not listed among the members and an effort should be made to have them join.

At a General Meeting of the Society held during the year one of the members of the Council, Mr. J. W. C. Wyett, made this position known and appealed to all members to assist in bringing interested and qualified persons into membership.

The Council feels that this question is not one for any one year or for any one person. If members would notify the Hon. Secretary or members of the Council of people who would be acceptable as members of the Society, the necessary approach could be made.

A. L. Meston Memorial: Some time ago a group of interested persons approached the Royal Society of Tasmania concerning a fitting memorial to commemorate the life and work of the late Mr. A. L. Meston. The Council referred the matter to the Nomenclature Board and asked that the Board consider giving Mr. Meston's name to some topographical feature in Tasmania. This has now been done and the lake at the headwaters of the Mersey River has been named "Lake Meston".

Papers and Proceedings: The Council is grateful to the Tasmanian Government for the amount of £550 provided as portion of cost of printing the Papers and Proceedings of the Royal Society.

The Council also would like to record its thanks for the help given by the University of Tasmania in providing a sum of money enabling the Society to publish certain works by members of the University staff in the Papers and Proceedings.

Rising costs have made it necessary for the Council to reconsider the whole question of printing the Papers. It is hoped that effective steps may be taken in the next twelve months to enable the Society to continue printing the Papers and Proceedings each year.

Northern Branch

Annual Report, 1955

At the Annual General Meeting of the Royal Society of Tasmania (Northern Branch), held at the Queen Victoria Museum on April 29th, 1955, the following were elected to the Council under the Rules of the Branch:

Council Members: Mr. G. H. Stancombe (1955, 1956); Dr. C. Craig (1955, 1956).

Hon. Secretary/Treasurer: Mr. W. F. Ellis (1955).

The following retained their offices for the following year:—

Chairman: Mr. R. Smith (1955).

Vice-Chairman: Mr. K. R. Von Stieglitz (1955).

Council Members: Mr. G. H. Crawford (1955); Mr. E. Padman (1955); Mr. B. H. Travers (1955).

The members present expressed their appreciation of the work done by the retiring members of Council, Mr. G. Willing and Mr. J. Rex.

Meetings: During the year seven General Meetings and one special Meeting were held at which the following papers were read:—

April 29th, 1955—"Sidelights and Sunlight on Nineteenth Century Buildings in Tasmania," by Mr. Roy Smith.

May 23rd, 1955—"The Evolution of English Furniture, with special reference to Historical Influences," by Dr. E. Graeme Robertson.

June 17th, 1955—"Some Results of Investigations into the Tasmanian Trout Fishery, with special reference to electrical fishing," by Dr. A. G. Nicholls.

July 29th, 1955—"An Outline of Tasmanian Natural History," by Mr. M. S. R. Sharland.

September 2nd, 1955—"A Scientist in America," by Professor H. N. Barber.

September 26th, 1955—"Tin Deposits in Tasmania, with special reference to Mt. Bischoff and Aberfoyle," by Mr. Wm. Hart.

November 28th, 1955—"The Growth of Local Government in Tasmania," by Mr. K. R. Von Stieglitz.

A special meeting in conjunction with the Adult Education Board was held on November 2nd, 1955, when Mr. Kenneth Townley spoke on "Dating the Past with radio-active isotopes".

Excursions: The Northern Branch conducted four excursions to the following places of historic interest:—

March 20th—"Everton" and "Harland Rise," led by Mr. K. R. Von Stieglitz.

May 1st—Christ Church, Illawarra; St. Marys Church, Hagley; and "Culzean" at Westbury, led by Mr. Roy Smith.

October 23rd—"Valleyfield," "Winton." and "St. Johnson," led by Mr. Hawley Stancombe.

November 13th—Mt. Direction Semaphore Station, led by Mr. Gordon Willing.

Membership: Sixteen members were elected during the year, the total Branch Membership now being:—

13 life members
139 ordinary members
12 associate members

Library: Four books were added to the Branch Library.

Publications: The edition of the "Penal Settlements of V.D.L.", by T. J. Lempriere, which was issued by the Branch, has been well received in Australia and a number of requests for copies have been received from institutions and retailers overseas. Although the wholesale and members' prices are almost at cost a substantial proportion of the initial expenditure has been recovered. It is hoped that Branch members will take advantage of the favourable price to distribute more copies locally.

The Council is at present considering the production of another similar publication.

Public Relations: The Branch has been represented by the Chairman or Hon. Secretary at a number of functions and active contact has been maintained with the General Council of the Society whose full co-operation and support we gratefully acknowledge.

Royal Society of Tasmania

(Northern Branch)

Statement of Accounts at December 31st, 1955

RECEIPTS.	£	s.	d.
Balance at 1.1.1955	69	17	9
Subscriptions	120	16	8
Bank interest	2	18	1
Sales of publications	41	12	2
	£235	4	8

EXPENDITURE.	£	s.	d.
Lectures	7	9	0
Library	9	2	5
Printing and advertising	75	1	6
Postage and petty cash	31	15	3
Balance carried forward	111	16	6
	£235	4	8

Examined and found correct.
J. R. FORWARD, Auditor.
Launceston, 10.1.56.

F. ELLIS, Hon. Secretary/Treasurer.

The Royal Society of Tasmania

Papers and Proceedings Volume 90

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A CATALOGUE OF THE TASMANIAN LEPIDOPTERA-RHOPALOCERA

By

L. E. Couchman
Hobart, Tasmania

Introduction

The many additions to the list of the Tasmanian butterflies, and the nomenclatorial changes consequent on a study of the literature, have placed additional and increasing difficulties in the path of students of this fascinating group. The references are scattered widely through journals here and abroad, and no detailed catalogue dealing solely with the Tasmanian species has ever been compiled.

Hardy (1916) and Turner (1926, 1939) published valuable lists of the species then known to be found in the State, but neither gave references to the literature nor adopted the trinomial system of nomenclature.

Tasmanian species had of course been included in catalogues prepared by workers on the Australian fauna. Semper's excellent list of the specimens in the Godeffroy Museum at Hamburg (1879) followed the monumental work of Kirby in 1871, from which Masters extracted the Australian species to form his 1873 catalogue. Miskin in 1891 prepared a catalogue which covered a vast amount of literature, perhaps never fully appreciated because so many extra-Australian references were included. The latest author, Waterhouse, in 1903 published a list which in many ways has formed the basis of subsequent classification, though the trinomial system was adopted only in the *Papilionidae*, and no complete list of references was attempted.

The standard works of Waterhouse and Lyell (1914) and Waterhouse (1932) placed the nomenclature on a proper basis, but later work is dispersed and often difficult of access.

The classification here adopted may seem strange when compared with that of Waterhouse or Seitz, but there can be no disagreement as to the need to bring our lists into line with work that has been done here and elsewhere. Zoologists generally agree that classification should begin with the most primitive forms and proceed to the most specialised, whereas some Australian authors begin with the most specialised groups and pass to the most primitive, others have begun with the less specialised *Papilionidae*, proceeded to the most highly specialised family, the *Satyridae*, and thence passed in more or less haphazard sequence to the primitive *Hesperiidae*. Let me add that Australian authors are not alone in these unscientific arrangements, the practice has been general, with but few notable exceptions. In England, Tutt, in the early years of this century, used this natural order, and more recently Warren (1947) emphasised

the logical nature of a classification that ascends in specialisation. The latter author also gives good reasons for regarding the *Satyridae* as the most highly specialised of all butterfly groups.

I have adopted Warren's arrangement for our comparatively few species, including only those references dealing with Tasmanian forms or which specifically mention Tasmania, excluding many Australian and other works concerned with areas outside this State or having no bearing on the local species.

The type and fixation of each genus is given and the present location of all types, so far as known to me, is included in an attempt to complete the work for all groups which Waterhouse in 1937 carried out so thoroughly for the *Hesperiidae*. The opportunity has also been taken to fix the exact type locality in a number of species where this has been in doubt, so that sub-specific population studies may be advanced.

Throughout the original spelling of specific names is retained, and in listing the literature under each species, the generic and specific names are not repeated where these are similar to the previous quotation.

Distribution records given are within the political boundaries of the State, including King and Flinders Islands, but ignoring the wider distribution outside these limits where this occurs.

During the years of research on a contemplated larger work on the Australian *Rhopalocera* I have personally consulted all but a few of the references given, where this has not been possible I have in great part depended on my friend A. Musgrave, whose help I acknowledge elsewhere.

Though fully conscious of the errors likely in work that must be done in leisure hours, I trust they are few and not serious in effect. I should appreciate help in noting omissions or in gaining additional information which could be incorporated in a work on the larger fauna of Australia.

Acknowledgments

The distributional records owe much to a number of friends whose help in accumulating material I have acknowledged in various publications during the past ten years.

Dr. W. Bryden, the Director, Tasmanian Museum, and Miss E. M. Geddes, Librarian, have aided me in obtaining books and in providing facilities for study. I am indebted to my friend A. N. Burns, Curator of Insects, National Museum of Victoria, for ready help whenever I have appealed to him, while in the study of the literature I have had valued assistance from my friends W. A. Rainbow, formerly Librarian, and A. Musgrave, Curator of Entomology, Australian Museum, Sydney, the latter's "*Bibliography* of *Australian Entomology*" has been an invaluable aid throughout years of research.

Finally my thanks are an inadequate return for the constant help in field and library given by my wife, her interest and assistance has made this work possible.

Order LEPIDOPTERA

Family: HESPERIIDAE

Sub-Family: *TRAPEZITINAE*

Genus: TRAPEZITES Hübner [1823] Zuträge z.s. exot. Schmett. 2: 10.
Type: *Trapezites symmommus* Hübner [1823] (sole species)

(*Trapezites* Hübner [1819] Verz. bek. Schmett. (7): 112) (M.S. name for one unpublished species)

Steropes Boisduval 1832 in d'Urville Voy "Astrolabe" Entom. I (Lepid.): 167.

Type: *Papilio iacchus* Fabricius 1775 (fixed by Lindsey 1925 Ann. ent. Soc. Amer. 18: 101).

Patlasingha Watson 1893. Proc. zool. Soc. Lond. 1893: 74-75.
Type: *Hesperia phigalia* Hewitson 1868 (fixed by author).

T. lutea lutea (Tepper) 1882. South Australia.

T. LUTEA GLAUCUS Waterhouse and Lyell 1914

Trapezites luteus glaucus Waterhouse and Lyell 1914, Butt. Australia: 177. pl. 34, f. 661; pl. 37, f. 739 ♂ ♀. *Trapezites glaucus* Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. *Trapezites luteus* forma *glaucus* Seitz 1927, Grossschmett. Erde 9: 1059. *Trapezites luteus glaucus* Waterhouse 1932, What Butt. is that?: 220. pl. 29, f. 9. *Trapezites lutea* forma *glaucus* Shepard 1936 in Strand Lepid. Catal. 77: 6. *Trapezites luteus* race *glaucus* Waterhouse 1937, Proc. linn. Soc. N.S.W. 62 (3/4): 113. *Trapezites lutea glaucus* Couchman 1947, Rec. Queen Vict. Mus. 2 (1): 5-6 (early stages). Evans 1949, Catal. Hesp. Europe, Asia and Aust.: 210.

lutea (nec Tepper 1882)

Trapezites lutea Meyrick and Lower 1902, Trans. Roy. Soc. South. Aust. 26: 90-91 (pt.). Waterhouse 1903, Mem. N.S.W. Natur. Club I: 44 (pt.). Lower 1911, Trans. Roy. Soc. South Aust. 35: 137 (pt.). *Anisynta lutea* Turner 1926, Pap. Proc. Roy. Soc. Tas. 1925: 123.

petalia (nec Hewitson 1868)

Telesto petalia Plötz 1884, Entom. Zeit. Stettin 45: 380. *Trapezites petalia Seitz* 1927, Grossschmett. Erde 9: pl. 167*g* (8).

Type Localities: Beauty Point. Launceston. Cressy. Karoola. Hobart. (Waterhouse and Lyell.) The holotype ♂ is from Hobart, 28th Dec. 1888, collected by J. J. Walker, I designate this the type locality.

Holotype ♂ and Allotype ♀: Australian Mus.

Distribution: Northern and eastern coastal areas to an altitude of c. 1,000 feet.

Genus: ANISYNTA Lower 1911 Trans. Roy. Soc. South Aust. 35: 141.
Type: *Cyclopides cynone* Hewitson 1874 (fixed by author).

A. DOMINULA DOMINULA (Plötz) 1884

Telesto dominula Plötz 1884, Entom. Zeit. Stettin 45: 379. ♂. *Hesperilla dominula* Miskin 1891, Ann. Queensl. Mus. 1: 81. *Telesto dominula* Meyrick and Lower 1902, Trans. Roy. Soc. South Aust. 26: 61. *Hesperilla dominula* Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 42. Lower 1911, Trans. Roy. Soc. South Aust. 35: 133. Waterhouse and Lyell 1912, Vict. Nat. 28: 225. *Motasingha dominula* Waterhouse and

Lyell 1914, Butt. Australia: 197 (pt.) (nec figs.). Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. Turner 1926, *loc. cit.* 1925: 123 (pt.). Seitz. 1927, Grossschmett. Erde 9: 1056 (pt.) pl. 168*b* (8, 9), 171*d* (3, 4). Waterhouse 1927, Proc. linn. Soc. N.S.W. 52 (3/4) : 278 (pt.). *Motasingha d. dominula* Waterhouse 1932, *loc. cit.* 57 (3) : 225. *Anisynta dominula* Waterhouse 1932, Aust. Zool. 7 (3) : 199, 200. *Anisynta d. dominula* Waterhouse 1932, What Butt. is that?: 236. *Motasingha dominula* Waterhouse 1933, Rec. South Aust. Mus. 5 (1) : 57. *Anisynta dominula* Shepard 1936 in Strand Lepid. Catal. 77: 12. *Anisynta d. dominula* Waterhouse 1937, Proc. linn. Soc. N.S.W. 62 (3/4) : 114. *Anisynta dominula* Waterhouse 1938, *loc. cit.* 63 (5/6) : 451. Couchman 1946, Pap. Proc. Roy. Soc. Tasm. 1945: 52. Burns [1948], Mem. Nat. Mus. (1947) 15: 106. *Anisynta d. dominula* Evans 1949, Catal. Hesp. Europe, Asia and Aust.: 212.

drachmophora (nec Meyrick 1885)

Telesto drachmophora Meyrick and Lower 1902, Trans. Roy. Soc. South Aust. 26: 61-62 (pt.).

Type Locality: Tasmania (Plötz) ; probably near Launceston (Waterhouse).

Holotype ♂: Not known.

Distribution: Northern and eastern coastal areas to an altitude of c. 1,000 feet.

A. Dominula Pria (Waterhouse) 1932

Motasingha dominula pria Waterhouse 1932, Proc. linn. Soc. N.S.W. 57 (3) : 225 ♂. *Anisynta dominula pria* Waterhouse 1932, What Butt. is that?: 236. Shepard 1936 in Strand Lepid. Catal. 77: 12. Waterhouse 1937, Proc. linn. Soc. N.S.W. 62 (3/4) : 114. Couchman 1946, Pap. Proc. Roy. Tasm. 1945: 52-53 ♀. Evans 1949, Catal. Hesp. Europe, Asia and Aust.: 212.

dominula (nec Plötz 1884)

Motasingha dominula Hardy 1918, Pap. Proc. Roy. Soc. Tasm. 1917: 68. Turner 1926, *loc. cit.*, 1925: 123 (pt.). Turner 1939, *loc. cit.*, 1938: 106.

Type Localities: Cradle Mountain (Waterhouse ♂); Cradle Mt. (Couchman neallotype ♀).

Waterhouse's reference to 5000 feet is an error, the specimens were taken at c. 3000 feet.

Holotype ♂: Australian Mus. Neallotype ♀: Tasmanian Mus.

Distribution: Western and central mountains at an altitude of 2500-3500 feet.

Genus: Hesperilla Hewitson 1868. Descr. 100 new spec. Hesp. (2): 37.
Type: *Hesperia ornata* Leach 1814 (fixed by author).

H. Idothea Idothea (Miskin) 1889

Trapezites idothea Miskin 1889, Proc. Roy. Soc. Queensl. 6 (3) : 152 ♀. *Telesto idothea* Meyrick and Lower 1902, Trans. Roy. Soc. South Aust. 26: 68-69 (early stages). *Hesperilla idothea* Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 43. Rainbow 1907, Guide study Aust. Butt.: 225. text f.: 227, f. 163; 228 (early stages). Lower 1911, Trans. Roy. Soc. South Aust. 35: 123 (pt.). Waterhouse and Lyell 1914, Butt. Australia:

187. pl. 35, f. 716, 717, 718. Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. Waterhouse 1923, Proc. linn. Soc. N.S.W. 48 (1): 22 (early stages). Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 123. Tillyard 1926, Ins. Aust. and N. Zeal.: 457. pl. 44, f. 4. Seitz 1927, Grossschmett. Erde 9: 1057. Waterhouse 1927, Proc. linn. Soc. N.S.W. 52 (3): 278. *Hesperilla i. idothea* Waterhouse 1932, *loc. cit.*, 57 (3/4): 227. *Hesperilla idothea* Waterhouse 1932, Aust. Zool. 7 (3): 200. *Hesperilla i. idothea* Waterhouse 1932, What Butt. is that?: 243. pl. 32, f. 8, 8A (early stages). *Hesperilla idothea* Waterhouse 1933, Rec. South Aust. Mus. 5 (1): 54. *Hesperilla i. idothea* Waterhouse 1934, Proc. linn. Soc. N.S.W. 59 (5/6): 414. *Hesperilla idothea* Shepard 1936 in Strand Lepid. Catal. 77: 25. *Hesperilla i. idothea* Waterhouse 1937, Proc. linn. Soc. N.S.W. 62 (3/4): 117. *Hesperilla idothea* Waterhouse 1938, *loc. cit.*, 63 (5/6): 451.

clara (nec Waterhouse 1932)

Hesperilla idothea clara Evans 1949, Catal. Hesp. Europe, Asia and Aust.: 217 (pt.).

dispar

Telesto dispar Kirby 1893, Ann. Mag. nat. Hist. (6) 12: 435-436 ♂ ♀. Meyrick and Lower 1902, Trans. Roy. Soc. South Aust. 26: 67-68.

Type Locality: Victoria (Miskin). Kirby's types were also described from Victoria.

Holotype ♀: South Australian Mus. The types of *dispar* are in the Brit. Mus. (Nat. Hist.).

Distribution: From Strahan to South Bruny through Hobart to Scottsdale, from sea level to c. 1000 feet.

H. donnysa donnysa Hewitson 1868. Sydney (Waterhouse 1941).

H. Donnysa Aurantia Waterhouse 1927

Hesperilla donnysa aurantia Waterhouse 1927, Proc. linn. Soc. N.S.W. 52 (3): 279-280. pl. 26, f. 5, 21, 22 ♂ ♀. Waterhouse 1932, What Butt. is that?: 241. Shepard 1936 in Strand Lepid. Catal. 77: 26. Waterhouse 1937, Proc. linn. Soc. N.S.W. 62 (3/4): 118. Waterhouse 1941, *loc. cit.*, 66 (3/4): 217. Evans 1949, Catal. Hesp. Europe, Asia and Aust.: 218. Burns 1951, Mem. Nat. Mus. 17: 83, 87-88, 95.

donnysa (nec Hewitson 1868)

Telesto donnysa Meyrick and Lower 1902, Trans. Roy. Soc. South Aust. 26: 64-65 (pt.). *Hesperilla donnysa* Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 43 (pt.). Rainbow 1907, Guide study Aust. Butt.: 231 (pt.). Lower 1911, Trans. Roy. Soc. South Aust. 35: 122-123 (pt.). Waterhouse and Lyell 1914, Butt. Australia: 188 (pt.). Hardy 1918, Pap. Proc. Roy. Soc. Tasm. 1917: 68. Turner 1926, *loc. cit.*, 1925: 123. Turner 1939, *loc. cit.*, 1938: 106.

Type Locality: Tasmania, Eaglehawk Neck.

Holotype ♂ and Allotype ♀: Australian Mus.

Distribution: Throughout the island from sea level to 3500 feet.

H. chrysotricha chrysotricha (Meyrick and Lower) 1902. West Australia.

H. Chrysotricha Plebeia Waterhouse 1927

Hesperilla chrysotricha plebeia Waterhouse 1927, Proc. linn. Soc. N.S.W. 52 (3): 281. pl. 26, f. 23, 24 ♂. Waterhouse 1932, What Butt. is that?: 242, pl. 32, f. 6. Shepard 1936 in Strand Lepid. Catal. 77: 27. Waterhouse 1937, Proc. linn. Soc. N.S.W. 62 (3/4): 118. Couchman 1949, Pap. Proc. Roy. Soc. Tasm. 1948: 66-67, 71, pl. 1, f. 5, 6 ♀. Evans 1949, Catal. Hesp. Europe, Asia and Aust.: 219.

cyclospila (nec Meyrick and Lower 1902)

Hesperilla chrysotricha cyclospila Waterhouse and Lyell 1914, Butt. Australia: 188 (pt.). pl. 34, f. 632. *Hesperilla cyclospila* Hardy 1918, Pap. Proc. Roy. Soc. Tasm. 1917: 67. Turner 1926, *loc. cit.*, 1925: 123.

Type Localities: Bridport (Waterhouse ♂). Latrobe (Couchman neallotype ♀).

Holotype ♂: Australian Mus. Neallotype ♀: Tasmanian Mus.

Distribution: North, East and south-east coastal and river shores.

H. Chrysotricha Lunawanna Couchman 1949

Hesperilla chrysotricha lunawanna Couchman 1949, Pap. Proc. Roy. Soc. Tasm. 1948: 68, 71 ♂ ♀.

plebeia (nec Waterhouse 1927)

Hesperilla chrysotricha plebeia Couchman 1947, Pap. Proc. Roy. Soc. Tasm. 1946: 29-30. pl. 1, f. 1-4.

Type Locality: Lunawanna, South Bruny Island.

Holotype ♂ and Allotype ♀: Tasmanian Mus.

Distribution: Coastal shores of D'Entrecasteaux Channel.

H. chaostola chaostola (Meyrick) 1888. Blackheath, N.S.W.

H. Chaostola Leucophaea Couchman 1946

Hesperilla chaostola leucophaea Couchman 1946, Pap. Proc. Roy. Soc. Tasm. 1945: 51-52 ♂ ♀. Evans 1949, Catal. Hesp. Europe, Asia and Aust.: 220.

chaostola (nec Meyrick 1888)

Telesto chaostola Meyrick and Lower 1902, Trans. Roy. Soc. South Aust. 26: 65-66 (pt.) (♀ only). *Hesperilla chaostola* Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 42 (pt.). Lower 1911, Trans. Roy. Soc. South Aust. 35: 132 (pt.). Waterhouse and Lyell 1914, Butt. Australia: 187 (pt.). Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 123. Waterhouse 1933, Rec. South Aust. Mus. 5 (1): 54 (pt.).

Type Locality: Kingston.

Holotype ♂ and Allotype ♀: Tasmanian Mus.

Distribution: Eastern coastal areas.

Genus: PASMA Waterhouse 1932, Aust. Zool. 7 (3): 198, 200.
Type: *Pasma tasmanica* Miskin, Waterhouse 1932 (= *Hesperilla tasmanicus* Miskin 1889) (fixed by author).

P. TASMANICUS (Miskin) 1889

Hesperilla tasmanicus Miskin 1889, Proc. Roy. Soc. Queensl. 6 (3): 149-150. ♂. (" ♀ " in err.) Miskin 1891, Ann. Queensl. Mus. 1: 81. *Trapezites tasmanicus* Meyrick and Lower 1902, Trans. Roy. Soc. South Aust. 26: 96-97. Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 45. *Anisynta tasmanicus* Lower 1911, Trans. Roy. Soc. South Aust. 35: 141. *Anisynta tasmanica* Waterhouse and Lyell 1914, Butt. Australia: 183. pl. 37, f. 750, 751. Hardy 1918, Pap. Proc. Roy. Soc. Tasm. 1917: 68. Turner 1926, *loc. cit.*, 1925: 123. *Anisynta tasmanicus* Seitz 1927, Grossschmett. Erde 9: 1060. *Anisynta tasmanica* Waterhouse 1927, Proc. linn. Soc. N.S.W. 52 (3/4): 277. *Pasma tasmanica* Waterhouse 1932, Aust. Zool. 7 (3): 198, 200. Waterhouse 1932, What Butt. is that?: 221. pl. 29, f. 13 (early stages). *Pasma tasmanicus* Shepard 1936 in Strand Lepid. Catal. 77: 13-14. Waterhouse 1937, Proc. linn. Soc. N.S.W. 62 (3/4): 114. *Anisynta tasmanica* Turner 1939, Pap Proc. Roy. Soc. Tasm. 1938: 106. *Pasma tasmanica* Evans 1949, Catal. Hesp. Europe, Asia and Aust.: 222.

comma

Telesto comma Kirby 1893, Ann. Mag. nat. Hist. (6) 12: 436. (" ♀ " in err.)

Type Localities: Tasmania (Miskin). Victoria (Kirby).

Holotype ♂ (nec ♀): Queensland Mus. Holotype ♂ of *comma* (nec ♀): Brit. Mus. (Nat. Hist.).

Distribution: Generally distributed from sea level to 3000 feet.

Sub-Family: *HESPERIINAE*

Genus: TARACTROCERA Butler [1870] Catal. diurn. Lepid. Fabr. Brit. Mus.: 279.
Type: *Hesperia maevius* Fabricius 1793 (fixed by author).
Bibla Mabille 1904 in Wytsmann Genera Insect. 17*b*: 122.
Type: *Hesperia papyria* Boisduval 1832 (sole species).

T. PAPYRIA PAPYRIA (Boisduval) 1832

Hesperia papyria Boisduval 1832 in d'Urville Voy. "Astrolabe" Ent. 1 (Lepid.): 166 ♂. Westwood 1852 in Doubleday Genera diurn. Lepid. (2): 527. *Taractrocera papyria* Kirby 1871, Synon. Catal. diurn. Lepid.: 626. Masters 1873, Catal. diurn. Lepid. Aust.: 24. Semper 1879, J. Mus. Godeffroy 5 (14): 193. Miskin 1891, Ann. Queensl. Mus. 1: 82, Addenda. Watson 1893, Proc. zool. Soc. Lond. 1893: 94. *Apaustus papyria* Meyrick and Lower 1902, Trans. Roy. Soc. South Aust. 26: 98-100 (early stages). Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 46. *Bibla papyria* Mabille 1904 in Wytsmann Genera Insect. 17*b*; 122. Lower 1911, Trans. Roy. Soc. South Aust. 35: 145 (early stages). *Taractrocera p. papyria* Waterhouse and Lyell 1914, Butt. Australia: 200. pl. 32, f. 580, 581. *Taractrocera papyria* Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. Turner 1926, *loc. cit.*, 1925: 123. Evans 1926, J. Bombay nat. Hist. Soc. 31: 625. Evans 1927, Ident. Indian Butt. ed. 1: 260. *Bibla papyria* Seitz 1927, Grossschmett. Erde 9: 1076. pl. 170*h* (1, 2). *Taractrocera p. papyria* Waterhouse 1932, Proc. linn. Soc. N.S.W. 57 (3/4): 228.

Waterhouse 1932, What Butt. is that?: 249 (early stage). pl. 32, f. 18, 18A. Waterhouse 1937, Proc. linn. Soc. N.S.W. 62 (3/4) : 120. *Taractrocera papyria* Shepard 1936 in Bryk Lepid. Catal. 90: 204. Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 106.

This widely spread species has received other names based on specimens from elsewhere in Australia.

Type Locality: New Holland (Boisduval). Sydney (designated by Waterhouse 1937).

Holotype ♂ : Not known. Waterhouse suggests it is probably in the Mus. Nat. d'Hist. nat. Paris.

Distribution: Coastal areas from sea level to 2000 feet.

Genus: OCYBADISTES Heron 1894, Ann. Mag. nat. Hist. (6) 14: 105-106. Type: *Ocybadistes walkeri* Heron 1894 (fixed by author).

O. walkeri walkeri Heron 1894. Damma Island.

O. WALKERI SOTHIS Waterhouse 1933

Ocybadistes walkeri sothis Waterhouse 1933, Proc. linn. Soc. N.S.W. 58 (5/6) : 465-466. ♂ ♀. Waterhouse 1937, *loc. cit.* 62 (3/4) : 122. Evans 1949, Catal. Hesp. Europe, Asia and Aust.: 366.

flavovittata (nec Latreille 1824)

Padraona f. flavovittata Waterhouse and Lyell 1914, Butt. Australia: 203 (pt.). pl. [42], f. 859. *Padraona flavovittata* Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. Turner 1926, *loc. cit.*, 1925: 123. *Padraona f. flavovittata* Waterhouse 1932, Proc. linn. Soc. N.S.W. 57 (3/4) : 232-233. Waterhouse 1932, What Butt. is that?: 253-254 (early stages). pl. 33, f. 9, 9A.

walkeri (nec Heron 1894)

Ocybadistes walkeri Lower 1911, Trans. Roy. Soc. South Aust. 35: 148-149 (pt.) (early stages). *Telicota walkeri* Seitz 1927, Grossschmett. Erde 9: 1079 (pt.). pl. 172*a* (6, 7). *Ocybadistis* (sic) *walkeri* Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 58, 106.

Type Locality: Sydney.

Holotype ♂ and Allotype ♀ : Australian Mus.

Distribution: North-west, north and eastern coastal areas from sea level to c. 750 feet.

Suniana lascivia lascivia (Rosenstock) 1885

This species, noted by Meyrick and Lower (1902), Lower (1911), Hardy (1916) and Turner (1926) from Tasmania has no place in our records. I showed in 1947 (Rec. Queen Vict. Mus. 2 (1) : 6) that records were evidently based on two specimens from Sydney now in the Tasmanian Mus., carrying G. A. Waterhouse's labels. Field work by a number of collectors in the subsequent eight years has only made it more certain that this species is not Tasmanian.

Family: PAPILIONIDAE

Sub-Family: *PAPILIONINAE*

Genus: GRAPHIUM Scopoli 1777, Intro. Hist. nat.: 433.

Type: *Papilio sarpedon* Linn. 1758 (fixed by Hemming 1933, Entom. Lond. 66: 199)

Zetides Hübner [1819] Verz. bek. Schmett. (6): 85.

Type: *Papilio sarpedon* Linn. 1758 (fixed by Scudder 1875, Proc. Am. Acad. Arts Sci. Boston 10: 292)

Chlorisses Swainson 1833, Zool. Illustr. (2) 2: pl. 89.

Type: *Papilio sarpedon* Linn. 1758 (sole species)

G. MACLEAYANUS MACLEAYANUS (Leach) 1814

Papilio macleayanus Leach 1814, Zool. Misc. 1: 17. pl. 5. ♀. Godart 1819, Ency. Meth. Hist. nat. (Zool.) 9 (1): 47. *Iphiclides macleayanus* Hübner [1824] Zutr. z. s. exot. Schmett. 3: pl. [87], f. 501, 502. ♂. Hübner [1827]-[1831] *loc. cit.* 3: 26. *Papilio macleayanus* Boisduval 1832 in d'Urville Vol. " Astrolabe " Ent. 1 (Lepid.): 42. Boisduval [1836] (Roret's Suite á Buffon) Lepid. 1: 229. Doubleday 1846, Genera diurn. Lepid. (1): 14. Gray [1853] Catal. Lepid. Ins. Brit. Mus. 1: 27. Kirby 1871, Synon. Catal. diurn. Lepid.: 561. Masters 1873, Catal. diurn. Lepid. Aust.: 2. Olliff 1888, Ann. Mag. nat. Hist. (6) 1: 358-359. pl. 20, f. 2-2c (early stages). Olliff 1889, Aust. Butt.: 35. *Papilio macleaynus* (sic) Miskin 1891, Ann. Queensl. Mus. 1: 5-6. *Papilio macleayanus* Olliff and Forde 1893 in Scott Aust. Lepid. 2: 31. pl. 20 (early stages). Rothschild 1895, Novit. Zool. 2: 424. Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 38. Rainbow 1907, Guide study Aust. Butt.: 202-206. text figs. 144, 145 (early stages). Froggatt 1907, Aust. Ins.: 226. Jordan 1909 in Seitz Grossschmett. Erde 9: 92. pl. 42a (2), 42b (3). Waterhouse and Lyell 1914, Butt. Aust.: 116. pl. 29, f. 555. Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. Hardy 1918, *loc. cit.* 1917: 68. Turner 1926, *loc. cit.* 1925: 122. Tillyard 1926, Ins. Aust. and N. Zeal.: 460. pl. 40, f. 2. Bryk 1930 in Strand Lepid. Catal. 37: 261. Waterhouse 1932, What Butt. is that?: 40-41 (early stages), pl. 5, f. 6. *Iphiclides macleayanus* Hemming 1937, Hübner 1: 474. *Papilio macleayanus* Waterhouse 1937, Rep. Aust. and N. Zeal. Ass. adv. Sci. 23: 127. Barrett and Burns 1951, Butt. Aust. and N. Guinea: 17-19. pl. 2, f. 6.

scottianus

Papilio scottianus Felder, C. 1862, Vehr. z.-bot. Ges. Wien 12: 489. Felder, C. and R. 1864, Reise d. " Novara " Zool. 2 (1): 73. Kirby 1871, Synon. Catal. diurn. Lepid.: 561.

Type Locality: Port Jackson (Leach).

Holotype ♀: Not known.

Distribution: Throughout the State in rain-forest areas from sea level to 5000 feet.

Family: PIERIDAE

Sub-Family: *PIERINAE*

Genus: PIERIS Schranck 1801, Fauna Boica 2 (1): 152, 161.

Type: *Papilio brassicae* Linn. 1758 (fixed by Latreille 1810, Consid. gén. Anim. Crust. Arachn. Ins.: 440.)

Ganoris Dalman 1816 K. Vet. Akad. Handl. 1816 (1): 61.

Type: *Papilio brassicae* Linn. 1758 (fixed by author)

Andropodum Hübner 1822, Syst. Alph. Verz.: 2-5, 7-9.

Type: *Papilio brassicae* Linn. 1758 (fixed by Hemming 1933, Entom. Lond. 66: 199)

Tachyptera Berge 1842, Schmetterlingsbuch: 19, 92-105.

Type: *Papilio brassicae* Linn. 1758 (fixed by Hemming 1934, Entom. Lond. 67: 38)

P. RAPAE RAPAE (Linn.) 1758

Papilio rapae Linn. 1758, Syst. Nat. ed. 10: 468. *Pieris r. rapae* Talbot 1932 in Strand Lepid. Catal. 53: 233-237. *Pieris rapae* Evans 1940, Tasm. J. Agric. 11 (4): 202-204. text. figs. Pearse 1941 in Dannreuther, Entom. Lond. 74: 188-189. Williams 1941, *loc. cit.* 74: 189-190. Evans 1943, Insect Pests: 80-81. 27, f. 37 (early stages). Evans 1943 in Dannreuther, Entom. Lond. 76: 262.

Distribution: This butterfly unfortunately occurs everywhere in the State.

I have seen it west of the DuCane Range in the Mountain Reserve, more than twenty miles from road or garden plot that would shelter a possible foodplant.

Full generic references are to be found in Talbot (1939: 413); the same author (1932: 233-237) has listed the references to this species before it became established in Australia. I have not included these, nor attempted the enormous economic literature.

Migrant and vagrant species include three *Pierinae; Eurema smilax* (Don.) noted by Pearse (1941) and Evans (1943); *Anapheis java teutonia* (Fabr.), noted by Hardy (1916), Williams (1941), Evans (1943) and Barret and Burns (1951): and *Appias paulina ega* (Boisduval), recorded by Turner (1926). These three species are casual visitors only, without any possibility of becoming established in the island.

Another possible vagrant is *Danaus chrysippus petilia* (Stoll) 1790 (*Danaidae*). Waterhouse and Lyell (1914: 17-18) include Zeehan among the localities for this species, doubtless noted by W. K. Findlay. Hardy (1916: 146) copies this, and Waterhouse (1937: 8) repeats his note, but Turner omits the species from his list. The register of the Waterhouse Coll. in the Aust. Museum contains a note under *Danaida chrysippus petilia*, "KL00163, 1 ♀ Zeehan, Tas. Feb. or Mar. 1907. per G. Lyell.". I know of no subsequent record, or of any other specimen from this State.

Family: LYCAENIDAE

Sub-Family: *LYCAENINAE*

Genus: CANDALIDES Hübner [1819] Verz. bek. Schmett. (5): 73.
Type: *Rusticus adolescens xanthospilos* Hübner [1817] (fixed by Scudder 1875, Proc. Amer. Acad. Arts Sci. Boston 10: 133)
Erina Swainson 1833, Zool. Illustr. (2) 3: pl. 134.
Type: *Erina erinus* Swainson 1833 (= *Papilio erinus* Fabricius 1775) (type by tautonomy)
Holochila Felder, C. 1862, Verh. zool.-bot. Ges. Wien 12 (1): 490.
Type: *Holochila absimilis* Felder 1862 (fixed by Waterhouse 1903: 145) (nom. preocc.)

C. ACASTA (Cox) 1873

Lycaena acasta Cox 1873, Entom. Lond. 6: 402. ♂. *Plebeius acasta* Kirby 1877, Synon. Catal. diurn. Lepid. Suppl.: 769. *Candalides acasta* Waterhouse 1903, Proc. linn. Soc. N.S.W. 28 (1): 186-187. pl. 2, f. 19; pl. 3, f. 7. Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 23. Waterhouse and Turner 1905, Proc. linn. Soc. N.S.W. 29 (4): 800. Waterhouse and Lyell 1914, Butt. Australia: 81. pl. 17, f. 344, 345. Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. Grünberg 1921 in Seitz Grossschmett. Erde 9: 852. Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 121. Waterhouse 1932, What Butt. is that?: 133. pl. 19, f. 11, 11A. Waterhouse 1937, Rep. Aust. and N. Zeal. Ass. adv. Sci. 23: 115. Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 106.

Lycaena canescens Miskin 1890, Proc. linn. Soc. N.S.W. (2) 5 (1): 35. Tasmania;

Holochila anita Semper 1879, J. Mus. Godeffroy 5 (14): 163. "Sidney, Cap York";

Lycaena maerens Rosenstock 1885, Ann. Mag. nat. Hist. (5) 16: 377. Melbourne,

are all names referable to this species.

Type Locality: South Australia.

Holotype ♂: Brit. Mus. (Nat. Hist.).

Distribution: Generally distributed throughout the State from sea level to 1000 feet.

Genus: LAMPIDES Hübner [1819] Verz. bek. Schmett. (5): 70.
Type: *Papilio boeticus* Linn. 1767 (fixed by Grote 1873, Bull. Buffalo Soc. nat. Sci. 1: 179)
Cosmolyce Toxopeus 1927, Tijdschr. Entom. 70: 268.
Type: *Papilio boeticus* Linn. 1767 (sole species)

L. BOETICUS DAMOËTES (Fabricius) 1775

Papilio damoëtes Fabricius 1775, Syst. Entom.: 526. Fabr. 1781, Spec. Ins. 2: 124. Fabr. 1787, Mantissa Ins. 2: 77. *Hesperia damoëtes* Fabr. 1793, Entom. Syst. 3 (1): 303. *Papilio damoëtes* Donovan 1805, Epit. nat. Hist. Ins. New Holl.: 66. pl. 31, f. 2. *Lampides boeticus damoëtes* Waterhouse 1932, What Butt. is that?: 173-174 (early stages). pl. 23, f. 15, 15A. *Lampides boeticus damoëtes* Couchman 1947, Rec. Queen Vict. Mus. 2 (1): 5.

boeticus (nec Linn. 1767)

Polyommatus boeticus Rainbow 1907, Guide study Aust. Butt.: 130-132, text f. 80, 81, 82 (early stages). pl. 3, f. 12. *Cosmolyce boeticus* Waterhouse 1937, Rep. Aust. and N. Zeal. Ass. adv. Sci. 23: 117 ("recently recorded from Tasmania").

Type Locality: New Holland (Fabr.). Donovan (1805) gives "Botany Bay", this can be accepted as the type locality. *L. boeticus damoëtes* flies in the Sydney district until June, and could have been taken during the "Endeavor's" visit, April 29-May 7, 1770.

Holotype: Brit. Mus. (Nat. Hist.), Banks Coll.

Distribution: Has occasionally been taken in the Hobart area, there are 6 males, 2 females in the Couchman Coll., and one pair from Launceston in the Waterhouse Coll., Aust. Mus.

Genus: ZIZINA Chapman 1910, Trans. ent. Soc. Lond. 1910: 482-483.
Type: *Polyommatus labradus* Godart 1824 (fixed by author).

Z. otis otis (Fabricius) 1787. China.

Z. OTIS LABRADUS (Godart) 1824

Polyommatus labradus Godart 1824, Ency. Meth. Hist. nat. (Zool.) 9 (2): 680. *Lycaena labradus* Boisduval 1832 in d'Urville Voy. "Astrolabe" Entom. 1 (Lepid.): 85. *Cupido labradus* Kirby 1871, Synon. Catal. diurn. Lepid.: 373. Masters 1873, Catal. diurn. Lepid. Aust.: 20. *Lycaena labradus* Miskin 1891, Ann. Queensl. Mus. 1: 62-63 (pt.). *Zizera labradus* Butler 1900, Proc. zool. Soc. Lond. 1900: 110 (pt.). Waterhouse 1903, Proc. linn. Soc. N.S.W. 28 (1): 214-215. pl. 3, f. 29. Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 26. Rainbow 1907, Guide study Aust. Butt.: 134-136, text f. 86, 87 (early stages). pl. 3, f. 15. *Zizina labradus* Waterhouse and Lyell 1914, Butt. Australia: 105. pl. 17, f. 380, 381. Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. *Zizera l. labradus* Seitz 1924, Grossschmett. Erde 9: 926. pl. 153*d* (4, 5, 6). *Zizina labradus* Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 121. Tillyard 1926, Ins. Australia and N. Zeal.: 466. *Zizera labradus* Seitz 1927, Grossschmett. Erde 9: 1115. *Zizeeria l. labradus* Waterhouse 1932, What Butt. is that?: 162, pl. 22, f. 14, 14A. *Zizeeria labradus* Waterhouse 1937, Rep. Aust. and N. Zeal. Ass. adv. Sci. 23: 113, 118 (early stages). *Zizina labradus* Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 106.

Type Locality: Port Jackson (Godart).

Holotype and Allotype: Not known.

Distribution: Generally distributed from sea level to 3500 feet. Chapman (1910: 489, 490) equated *otis* to *labradus*, but continued to use the later name for the collective species, which has a vast geographical range, with a correspondingly large nomenclature.

I have not attempted to list the many synonyms for the Australian sub-species.

Genus: NEOLUCIA Waterhouse and Turner 1905, Proc. linn. Soc. N.S.W. 29 (4): 803.

Type: "*Lycaena*" *agricola* Westwood, Waterhouse and Turner 1905 (= *Lucia agricola* Westwood [1851] (fixed by authors).

N. AGRICOLA AGRICOLA (Westwood) [1851]

Lucia agricola Westwood [1851] in Doubleday Genera diurn. Lepid. (2): pl. 76, f. 4. *Lycaena agricola* Westwood [1852] *loc. cit.* (2): 496. *Plebeius agricola* Kirby 1871, Synon. Catal. diurn. Lepid.: 376. *Cupido agricola* Masters 1873, Catal. diurn. Lepid. Aust.: 19. Miskin 1891, Ann. Queensl. Mus. 1: 63. *Una agricola* Waterhouse 1903, Proc. linn. Soc. N.S.W. 28 (1): 234-235. pl. 3, f. 26. Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 27. *Neolucia agricola* Waterhouse and Turner 1905, Proc. linn. Soc. N.S.W. 29 (4): 803. *Neolucia a. agricola* Waterhouse and Lyell 1914, Butt. Australia: 107, pl. 17, f. 370, 372. *Neolucia agricola* Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. *Lucia a. agricola* Seitz 1926, Grossschmett. Erde 9: 930. pl. 153h (2, 3). *Neolucia agricola* Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 121 (pt.). Tillyard 1926, Ins. Aust. and N. Zeal.: 466. *Neolucia a. agricola* Waterhouse 1932, What Butt. is that?: 169. pl. 23, f. 8, 8A. *Neolucia agricola* Waterhouse 1937, Rep. Aust. and N. Zeal. Ass. adv. Sci. 23: 113, 118 (early stages). Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 106 (pt.). *Neolucia a. agricola* Barrett and Burns 1951: 156.

Type Locality: Australia (Westwood). Sydney (Waterhouse 1937.)

Holotype and Allotype: Not known.

Distribution: Northern and eastern areas of the State from sea level to c. 2000 feet.

N. AGRICOLA INSULANA Waterhouse and Lyell 1914

Neolucia agricola insulana Waterhouse and Lyell 1914, Butt. Australia: 107. pl. 17, f. 371. *Neolucia insulana* Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. *Lucia agricola* form *insulana* Seitz 1927, Grossschmett. Erde 9: 1115. *Neolucia agricola insulana* Waterhouse 1932, What Butt. is that?: 169.

agricola (nec Westwood 1851)

Neolucia agricola Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 121 (pt.).

Type Locality: Zeehan.

Holotype ♂ and Allotype ♀: Australian Mus.

Distribution: West Coast areas from sea level to c. 2500 feet.

N. HOBARTENSIS HOBARTENSIS (Miskin) 1890

Lycaena hobartensis Miskin 1890, Proc. linn. Soc. N.S.W. 5 (1): 38-39. ♀. Miskin 1891, Ann. Queensl. Mus. 1: 63. *Una hobartensis* Waterhouse 1903, Proc. linn. Soc. N.S.W. 28 (1): 235-236 ♂. Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 28. *Neolucia h. hobartensis*

Waterhouse and Lyell 1914, Butt. Australia: 102. pl. 17, f. 373, 376. *Neolucia hobartensis* Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. *Neolucina* (sic) *hobartensis* Hardy 1918, *loc. cit.*, 1917: 68. *Lucia agricola hobartensis* Seitz 1924, Grossschmett. Erde 9: 930. *Neolucia hobartensis* Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 121. Tillyard 1926, Ins. Aust. and N. Zeal.: 466. *Neolucia h. hobartensis* Waterhouse 1932, What Butt. is that?: 170. pl. 23, f. 9, 9A. *Neolucia hobartensis* Waterhouse 1937, Rep. Aust. and N. Zeal. Ass. adv. Sci. 23: 118 (early stages). Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 106.

Type Locality: Hobart (Miskin). Mt. Wellington, near Hobart. (Waterhouse 1928.)

Holotype ♀: Queensland Mus. Neallotype ♂: Australian Mus.

Distribution: Alpine areas from 1000-4200 feet.

N. Mathewi (Miskin) 1890

Lycaena mathewi Miskin 1890, Proc. linn. Soc. N.S.W. 5 (1): 38 ♂. Miskin 1891, Ann. Queensl. Mus. 1: 63. *Una mathewi* Waterhouse 1903, Proc. linn. Soc. N.S.W. 28 (1): 234, 236, pl. 2, f. 9. Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 28. *Neolucia mathewi* Waterhouse and Lyell 1914, Butt. Australia: 108. pl. 17, f. 384, 385, 386. Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. *Lucia mathewi* Seitz 1924, Grossschmett. Erde 9: 930. *Neolucia mathewi* Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 121. Waterhouse 1932, What Butt. is that?: 171. pl. 23, f. 11, 11A. Waterhouse 1937, Rep. Aust. and New Zeal. Ass. adv. Sci. 23: 118 (early stages). Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 106.

Type Locality: Sydney (Miskin).

Holotype ♂: Queensland Mus.

Distribution: North-east Tasmania, Flinders Island.

N. Serpentata Serpentata (Herrich-Schäffer) 1869

Lycaena serpentata Herrich-Schäffer 1869, Entom. Zeit. Stettin 30: 74. *Plebeius serpentata* Kirby 1871, Synon. Catal. diurn. Lepid.: 360. *Cupido serpentata* Masters 1873, Catal. diurn. Lepid. Aust.: 20. *Lycaena serpentata* Miskin 1891, Ann. Queensl. Mus. 1: 63. *Una serpentata* Waterhouse 1903, Proc. linn. Soc. N.S.W. 28 (1): 238. Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 28. *Neolucia serpentata* Waterhouse and Lyell 1914, Butt. Australia: 108. pl. 17, f. 377, 387, 388. *Lucia serpentata* Seitz 1924, Grossschmett. Erde 9: 930. *Neolucia serpentata* Waterhouse 1932, What Butt. is that?: 171-172. pl. 23, f. 12, 12A. Waterhouse 1937, Rep. Aust. and New Zeal. Ass. adv. Sci. 23: 118. *Neolucia s. serpentata* Couchman 1954, Pap. Proc. Roy. Soc. Tasm. 88: 75.

Type Locality: Rockhampton, Queensland.

Holotype and Allotype: Not known.

Distribution: Whitemark, Flinders Island.

N. SERPENTATA LAVARA Couchman 1954

Neolucia serpentata lavara Couchman 1954, Pap. Proc. Roy. Soc. Tas. 88: 75 ♂ ♀.

Type Locality: Cambridge, sea level.

Holotype ♂: Couchman Coll. Allotype ♀: Tasmanian Mus.

Distribution: Coastal mud-flats of the south-eastern area.

Sub-Family: *LUCIINAE*

Genus: PARALUCIA Waterhouse and Turner 1905, Proc. linn. Soc. N.S.W. 29 (4): 802.

Type: *Lucia pyrodiscus* Rosenstock 1885 (nec Doubleday 1847) (= *Chrysophanus acnea* Miskin 1890) (fixed by authors).

P. AURIFER (Blanchard) [1848]

Thecla aurifer Blanchard [1848] in d'Urville Voy. au Pôle Sud, Zool. Atlas Ins.: pl. 3, f. 13, 14. [♂]. Chenu 1869, Ency. Hist. nat. Papillons: 280. f. 489. *Lucia aurifer* Kirby 1871, Synon. Catal. diurn. Lepid.: 337. Masters 1873, Catal. diurn. Lepid. Aust.: 18. *Lycaena aurifer* Butler 1875, Trans. ent. Soc. Lond. 1875 (1): 10. *Chrysophanus aurifer* Miskin 1890, Proc. linn. Soc. N.S.W. 5 (1): 31-32. Miskin 1891, Ann. Queensl. Mus. 1: 48. *Lucia aurifer* Waterhouse 1903, Proc. linn. Soc. N.S.W. 28 (1): 204-205. Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 28. *Paralucia aurifer* Waterhouse and Lyell 1914, Butt. Australia: 112. pl. 15, f. 249, 250, 251. Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. Turner 1926, *loc. cit.*, 1925: 121. *Paralucia aurifera* (sic) Tillyard 1926, Ins. Aust. and New Zeal.: 465. pl. 40, f. 8. *Lucia aurifer* Seitz 1926, Grossschmett. Erde 9: 931. *Paralucia aurifer* Waterhouse 1932, What Butt. is that?: 167. pl. 23, f. 5, 5A. Waterhouse 1937, Rep. Aust. and New Zeal. Ass. adv. Sci. 23: 119 (early stages). Barrett and Burns 1951, Butt. Aust. and New Guinea: 155. pl. 8, f. 11.

limbaria (nec Swainson 1833)

Thecla limbaria Doubleday 1847, List spec. Lepid. Ins. Brit. Mus. 2: 57. Blanchard 1853 in d'Urville Voy. au Pôle Sud, Zool. 4: 400.

pyrodiscus (Leach M.S.)

Thecla pyrodiscus (Leach M.S.) Doubleday 1847, List spec. Lepid. Ins. Brit. Mus. 2: 57 (nom. nud.).

lucanus (nec Fabricius 1793)

Zeritis lucanus Butler [1870] Catal. Lepid. Fabr. Brit. Mus.: 178.

Type Locality: Tasmania (Blanchard). Since Blanchard figured and described other insects from Hobart I designate this the type locality.

Holotype ♂: Not known.

Distribution: Northern, eastern and southern areas from sea level to c. 1100 feet.

Genus: PSEUDALMENUS Druce, H. H., 1902, Proc. zool. Soc. Lond. 1902: 116-117.

Type: *Thecla myrsilus* Doubleday and Hewitson, Druce 1902 (= *Thecla chlorinda* Blanchard [1848] (fixed by author).

P. CHLORINDA CHLORINDA (Blanchard) [1848]

Thecla chlorinda Blanchard [1848] in d'Urville Voy. au Pôle Sud, Zool. Atlas Ins.: pl. 3, f. 15, 16 ♂; 17, 18 ♀. Westwood [1852] in Doubleday Genera diurn. Lepid. (2): 487. Blanchard 1853 in d'Urville Voy. au Pôle Sud, Zool. 4: 401. *Pseudalmenus chlorinda* Waterhouse 1913, Proc. linn. Soc. N.S.W. 37 (4): 701. *Pseudalmenus c. chlorinda* Waterhouse and Lyell 1914, Butt. Australia: 113. pl. [42], f. 863, 864. *Pseudalmenus chlorinda* Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. Turner 1926, *loc. cit.* 1925: 121. Tillyard 1926, Ins. Aust. and New Zeal.: 465. *Pseudalmenus c. chlorinda* Waterhouse 1928, Proc. linn. Soc. N.S.W. 53 (4): 410-411. pl. 25, f. 1-4. Waterhouse 1932, What Butt is that?: 192. pl. 26, f. 13. Burns [1948] Mem. Nat. Mus. 15 (1947): 97, 98. *Pseudalmenus chlorinda* Couchman 1948, Rec. Queen Vict. Mus. 2 (2): 95-96. *Pseudalmenus c. chlorinda* Tindale 1953, Rec. South Aust. Mus. 11 (1): 52, 55, pl. 20, f.d.

myrsilus

Ialmenus myrsilus Doubleday 1847, List spec. Lepid. Ins. Brit. Mus. (2): 28 (nom. nud.). Westwood [1851] in Doubleday Genera diurn. Lepid. (2): pl. 75, f. 3. ♀. *Thecla myrsilus* Westwood [1852] *loc. cit.* (2): 487. *Ialmenus myrsilus* Kirby 1871, Synon. Catal. diurn. Lepid.: 406. Masters 1873, Catal. diurn. Lepid. Aust.: 21. Olliff 1889, Aust. Butt.: 24. Miskin 1891, Ann. Queensl. Mus. I: 68 (pt.). *Pseudalmenus myrsilus* Waterhouse 1903, Proc. linn. Soc. N.S.W. 28 (1): 260-261 (pt.) pl. 3, f. 23. Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 30 (pt.). Froggatt 1907, Aust. Ins.: 222 (pt.). *Jalmenus m. myrsilus* Seitz 1926, Grossschmett. Erde 9: 998. *Ialmenus myrsilus* Hemming 1941, J. Soc. bibliogr. nat. Hist. I (II): 458.

Type Locality: Tasmania (Blanchard). It is certain that the description was based on specimens from the Hobart area, the exact locality is the subject of study now in progress.

Holotype ♂ and Allotype ♀: Not known. As I have noted (1948) the types could not be found in Paris.

Distribution: Hobart district; East Coast; Launceston district.

Family: NYMPHALIDAE

Sub-Family: NYMPHALINAE

Genus: PRECIS Hübner [1819] Verz. bek. Schmett. (3): 33.
Type: *Papilio octavia* Cramer 1777 (fixed by Scudder 1875, Proc. Amer. Acad. Arts Sci. Boston 10: 256).

P. villida villida (Fabricius) 1787. Amsterdam Is. (Tongatabu).

P. VILLIDA CALYBE (Godart) 1819.

Vanessa calybe Godart 1819, Ency. Meth. Hist. nat. (Zool.) 9 (1): 317. *Precis villida calybe* Waterhouse 1932, What Butt. is that?: 88.

pl. 13, f. 2. *Precis villida* race *calybe* Waterhouse 1937, Rep. Aust. and N. Zeal. Ass. adv. Sci. 23: 111 (early stages). *Precis villida calybe* Barrett and Burns 1951, Butt. Aust. and N. Guinea: 135.

villida (nec Fabricius 1787)

Precis villida Butler 1901, Ann. Mag. nat. Hist. (7) 8: 197 (pt.). *Junonia villida* Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 12. Rainbow 1907, Guide study Aust. Butt.: 75-76. text f. 45, 46, 47 (early stages). 63, fig. *Precis v. villida* Fruhstorfer 1912 in Seitz Grossschmett. Erde 9: 521-522. pl. 116e (5, 6). Waterhouse and Lyell 1914, Butt. Australia: 54. pl. 5, f. 25. *Precis villida* Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. Watkins 1923, Entom. Lond. 56: 205, 206. Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 122. Tillyard 1926, Ins. Aust. and N. Zeal.: 463. pl. 43, f. 13. Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 106.

vellida

Junonia vellida Kirby 1871, Synon. Catal. diurn. Lepid.: 188 (pt.) *Junonisa* (sic) *vellida* Masters 1873, Catal diurn. Lepid. Aust.: 13. *Junonia vellida* Miskin 1891, Ann. Queensl. Mus. 1: 40.

Type Locality: New Holland (Godart). The Port Jackson district would certainly be the type locality.

Holotype and Allotype: Not known.

Distribution: Northern, eastern and southern areas to c. 1000 feet.

Genus: VANESSA Fabricius 1807, Mag. f. Insekt. (Illiger) 6: 281.
Type: *Papilio atalanta* Linn. 1758 (fixed by Latreille 1810, Consid. gén. Anim. Crust. Arachn. Ins. 440).
Cynthia Fabricius 1807, Mag. f. Insekt. (Illiger) 6: 281.
Type: *Papilio cardui* Linn. 1758. (*Vanessa* to have precedence, Intern. Comm. Zool. Nomencl. Opinion 156.)
Pyrameis Hübner [1819] Verz. bek. Schmett. (3) 33.
Type: *Papilio atalanta* Linn. 1758 (fixed by Scudder 1875, Proc. Amer. Acad. Arts Sci. Boston 10: 260).
Bassaris Hübner [1821] Samml. exot. Schmett. 2: pl. [24].
Type: *Papilio itea* Fabricius 1775 (sole species).

V. cardui cardui (Linn.) 1758. Europe.

V. CARDUI KERSHAWI (McCoy) 1868

Cynthia kershawi McCoy 1868, Ann. Mag. nat. Hist. (4) 1: 76. *Pyrameis cardui* var. *kershawii* Kirby 1871, Synon. Catal. diurn. Lepid.: 185. *Pyrameis kershawi* McCoy 1890, Nat. Hist. Victoria 2 (20) : 363-367. pl. 198, f. 5, 5a, 6, 7, 7a, 7b, 8 (early stages). *Pyrameis kershawii* Miskin 1891, Ann. Queensl. Mus. 1: 39. *Pyrameis kershawi* Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 12. Rainbow 1907, Guide study Aust. Butt.: 63, figs. 70-73. text f. 41 (early stages). Froggatt 1907, Aust. Ins.: 216. *Pyrameis cardui kershawi* Fruhstorfer 1912 in Seitz Grossschmett. Erde 9: 525. Waterhouse and Lyell 1914, Butt. Australia:

56. pl. 5, f. 36. *Pyrameis kershawi* Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. *Pyrameis cardui kershawi* Tillyard 1926, Ins. Aust. and N. Zeal.: 463. Waterhouse 1932, What Butt. is that?: 90. pl. 13, f. 5. *Vanessa cardui kershawi* Waterhouse 1937, Rep. Aust. and N. Zeal. Ass. adv. Sci. 23: 111 (early stages). *Pyrameis cardui kershawi* Barrett and Burns 1951, Butt. Aust. and N. Guinea: 134.

cardui (nec Linn. 1758)

Pyrameis cardui Froggatt 1907, Aust. Ins.: pl. 20, f. 6. Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 122. Turner 1939, *loc. cit.*, 1938: 106.

Type Locality: "about Melbourne and in many other parts of Australia" (McCoy). Melbourne thus is the type locality.

Holotype and Allotype: The National Museum of Victoria has two females in the Lyell Coll., one or the other of which may be the original specimen. The first, without antennae, bears a label "Victorian", which my friend A. N. Burns believes to be in the handwriting of W. Kershaw. The second, probably a female, without head, body or antennae, is labelled "*Pyrameis kershawi* (McCoy). Near Melbourne. Drawing 67." A careful search has revealed no other specimen that could possibly be the holotype, it seems that although damaged the latter is more likely to be McCoy's original specimen.

Distribution: Throughout the State from sea level to c. 3000 feet.

V. Itea (Fabricius) 1775

Papilio itea Fabricius 1775, Syst. Entom.: 498. Fabricius 1781, Spec. Ins. 2: 82. Fabricius 1787, Mant. Ins. 2: 45. Fabricius 1793, Entom. Syst. 3 (1): 103. Donovan 1805, Epit. nat. Hist. Ins. New. Holl.: [57]. pl. 26, f. 1. *Vanessa itea* Godart 1819, Ency. Meth. Hist. nat. (Zool.) 9 (1): 321. *Bassaris itea* Hübner [1821] Samml. exot. Schmett. 2: pl. [24]. *Vanessa itea* Boisduval 1832 in d'Urville Voy. Astrolabe Entom. I (Lepid.): 121. *Pyrameis itea* Butler [1870] Catal. diurn. Lepid. Fabr. Brit. Mus.: 78. Kirby 1871, Synon. Catal. diurn. Lepid.: 185. McCoy 1890, Nat. Hist. Victoria 2 (20): 361-363. pl. 198, f. I, Ia-Ie, 2, 3, 3a, 4 (early stages). Miskin 1891, Ann. Queensl. Mus. 1: 39. Waterhouse 1903, Mem. N.S.W. Natur. Club I: II. Rainbow 1907, Guide study Aust. Butt.: 67-68, 70. text f. 38, 39, 40 (early stages). Froggatt 1907, Aust. Ins.: 216. pl. 20, f. 5. Fruhstorfer 1912 in Seitz Grossschmett. Erde 9: 526. pl. 117d (5), 117e (1). Waterhouse and Lyell 1914, Butt. Australia: 56. pl. 5, f. 34. Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. Hardy 1918, *loc. cit.*, 1917: 68. Watkins 1923, Entom. Lond. 56: 205, 206. Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 122. Tillyard 1926, Ins. Aust. and N. Zeal.: 463. pl. 40, f. 12. *Papilio itea* Gabriel 1927, Catal. Type spec. Lepid. Rhop. Brit. Mus. 3: 65. *Pyrameis itea* Waterhouse 1932, What Butt. is that?: 90. pl. 13, f. 6. *Vanessa itea* Waterhouse 1937, Rep. Aust. and N. Zeal.

Ass. adv. Sci. 23: 111 (early stages). *Pyrameis itea* Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 106. Barrett and Burns 1951, Butt. Aust. and N. Guinea: 134-135. text f.

Type Locality: New Zealand (Fabricius).

Holotype ♂: Brit. Mus. (Nat. Hist.).

Distribution: Throughout the State from sea level to c. 3000 feet.

Family: DANAIDAE

Sub-Family: *DANAINAE*

Genus: DANAUS Kluk 1780, Zwierz. Hist. nat. pocz. gospod. 4: 84.
Type: *Papilio plexippus* Linn. 1758 (fixed by Hemming 1933, Entom. Lond. 66: 222).
Danaida Latreille 1804, Nouv. Dict. Hist. nat. 24: 185, 199.
Type: *Danaida plexippus* Fabr., Latreille 1804 (= *Papilio plexippus* Linn. 1758).
Danais Latreille 1807, Mag. f. Insekt. (Illiger) 6: 291.
Type: *Papilio plexippus* Linn. 1758.

D. PLEXIPPUS PLEXIPPUS (Linn.) 1758

Papilio plexippus Linn. 1758, Syst. Nat. ed. 10: 471. Cramer 1779, Uitl. Kapellen 3 (8): 24. pl. 206, f. E, F. *Anosia plexippus* Walker 1886, Entom. mon. Mag. 22: 220. *Danais plexippus* Olliff 1889, Aust. Butt.: 9-10, text f. *Danaida plexippus* Waterhouse 1932, What Butt. is that?: 70-71 (early stages). pl. 11, f. 1. *Danaus plexippus* Pearse 1938 in Dannreuther, Entom. Lond. 71: 237. Dannreuther 1941, *loc. cit.*, 79: 189. Pearse 1943 in Dannreuther, *loc. cit.*, 76: 262. *Danaida plexippus* Evans 1943, Insect Pests: 80. Barrett and Burns 1951, Butt. Aust. and N. Guinea: 70-72. text f. *Papilio plexippus* Linn. Intern. Comm. Zool. Nomencl. Opinion 282, 1954; 6 (14): 225-268. pl. 2.

archippus (nec Cramer 1775)

Danais archippus Miskin 1871, Entom. mon. Mag. Lond. 8: 17. *Danaida archippus* Waterhouse and Lyell 1914, Butt. Australia: 16. pl. 1, f. 1. Tillyard 1926, Ins. Aust. and N. Zeal.: 461-462. text f. Z65, 66 (early stages). *Danaida a. archippus* Hulstaert 1931 in Wytsmann Genera Ins. 193: 21.

erippus (nec Cramer 1775)

Danais erippus Miskin 1891, Ann. Queensl. Mus. 1: 23-24.

menippe

Danaus (*Anosia*) *menippe* Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 8. Rainbow 1907, Guide study Aust. Butt.: 44-46, 47, text f. pl. 1. text f. 21, 22 (early stages). *Danais menippe* Froggatt 1907, Aust. Ins.: 214.

curassavicae

Danaus (*Anosia*) *curassavicae* Bryk 1937, Lepid. Catal. 78: 42-47.

Type Locality: Kendall, New York State.

Neotype ♂: U.S. National Mus.

Distribution: Specimens have been noted in the Tasmanian and Queen Victoria Museums.

This species, known for a number of years as an occasional visitor, has suffered more than any butterfly in the world through disagreement as to its correct specific name. In Australia at various times *plexippus, archippus, erippus* and *menippe* have been in use, only *curassavicae* seems to have been left unused.

The name was fixed when the International Commission on Zoological Nomenclature accepted Corbet's proposal at its Paris meeting in July, 1948, that *plexippus* should be retained for the North American Monarch butterfly, not for the Oriental species. Subsequent discussion is merely academic, apart from the Commission's error in selecting Holland's figure of a South American specimen in the belief that it was actually the North American subspecies. This action has now been rectified, and a neotype selected and figured. The example is from New York State, figured in 1941 by Clark, H. A. "Notes on some North and Middle American Danaid Butterflies" (Proc. U.S. nat. Mus. 90: 533-536. pl. 71, f. 1.).

Tindale's remarks (1953, Rec. South Aust. Mus. 11 (1): 60) regarding this insect are erroneous, Corbet (1949, Proc. R. ent. Soc. Lond. (B) 18 (9/10): 184-190) did not select as lectotype a Chinese specimen in the Linnean Coll., actually it was Corbet's application, made in November 1947, for the restriction of the name *plexippus* to the North American butterfly which was accepted by the Commission some months later.

I have given the Tasmanian and the more important Australian references, the complete generic and specific references are listed by Hulstaert, Bryk and in the International Commission's Opinion 282.

Family: SATYRIDAE

Genus: NESOXENICA Waterhouse and Lyell 1914, Butt. Australia: 35.

Type: *Nesoxenica leprea* Hewitson, Waterhouse and Lyell 1914 (= *Lasiommata leprea* Hewitson 1864) (sole species).

Xeniconympha Novickij 1923, Sborn. ent. Odd. nár. Mus. Praze 1: 60.

Type: *Lasiommata leprea* Hewitson 1864 (fixed by author).

N. LEPREA LEPREA (Hewitson) 1864

Lasiommata leprea Hewitson 1864, Trans. ent. Soc. Lond. (3) 2: 249. pl. 16, f. 6, 7 ♀. *Argynnina leprea* Butler 1868, Catal. Satyridae Brit. Mus.: 166. *Xenica leprea* Kirby 1871, Synon. Catal. diurn. Lepid.: 76. Masters 1873, Catal, diurn. Lepid. Aust.: 15. *Argynnina leprea* Semper 1879, J. Mus. Godeffroy 5 (14): 189. *Xenica leprea* Olliff 1889, Aust. Butt.: 20. Miskin 1891, Ann. Queensl. Mus. 1: 30. Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 18. *Xenica lepera* (sic) Fruhstorfer 1911 in Seitz Grossschmett. Erde 9: 304. *Nesoxenica l. leprea* Waterhouse and Lyell 1914, Butt. Australia: 36. pl. 12, f. 131. *Nesoxenica leprea* Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. *Xeniconympha leprea* Novickij 1923, Sborn. ent. Odd. nár. Mus. Praze 1: 60. *Lasiom-*

mata leprea Riley and Gabriel 1924, Catal. Type spec. Lepid. Rhop. Brit. Mus. 1: 31. *Nesoxenica leprea* Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 81 (pt.), 122 (pt.). Tillyard 1926, Ins. Aust. and N. Zeal.: 462. pl. 43, f. 8. *Xenica leprea* Gaede 1931 in Strand Lepid. Catal. 43: 82. *Nesoxenica l. leprea* Waterhouse 1932. What Butt. is that?: 120. pl. 17, f. 12. *Xeniconympha leprea* Waterhouse 1936, Proc. R. ent. Soc. Lond. (B) 5 (9): 173 (*Xeniconympha* a syn. of *Nesoxenica*). *Nesoxenica leprea* Waterhouse 1937, Rep. Aust. and N. Zeal. Ass. adv. Sci. 23: 107. *Nesoxenica l. leprea* Couchman 1946, Pap. Proc. Roy. Soc. Tasm. 1945: 49. Barrett and Burns 1951, Butt. Aust. and N. Guinea: 55-56. pl. 3, f. 5.

Type Locality: Australia (Hewitson). I have earlier (1946) suggested that the original specimen came from Mt. Wellington at about 2500 feet, I designate this as the type locality.

Holotype ♀: Brit. Mus. (Nat. Hist.).

Distribution: Mt. Wellington, 1500-3000 feet; Esperance River area c. 300 feet; Hastings Caves district c. 500 feet; National Park, 1000-2500 feet.

N. Leprea Elia Waterhouse and Lyell 1914

Nesoxenica leprea elia Waterhouse and Lyell 1914, Butt. Australia: 36. pl. 12, f. 132, 133 ♂ ♀. *Nesoxenica elia* Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. Hardy 1918, *loc. cit.*, 1917; 67, 68. *Nesoxenica leprea elia* Waterhouse 1932. What Butt. is that?: 121. pl. 17, f. 13. Couchman 1946, Pap. Proc. Roy. Soc. Tasm. 1945: 50. *Nesoxenica leprea* race *elia* Barrett and Burns 1951, Butt. Aust. and N. Guinea: 55.

leprea (nec Hewitson 1864)

Neoxenica (sic) *leprea* Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 145. *Nesoxenica leprea* Turner 1926, *loc. cit.* 1925: 81 (pt.), 122 (pt.).

Type Locality: Mt. Dundas. Mt. Magnet. (Waterhouse and Lyell.) The holotype male and allotype female came from Mt. Dundas. I designate this the type locality.

Holotype ♂ and Allotype ♀: Australian Mus.

Distribution: Cradle Mt. to Lake St. Clair west to Mt. Dundas, from c. 2500-3850 feet.

Genus: Heteronympha Wallengren 1858, Öfv. Svenska Vet.-Akad. Förhandl. 15: 78.

Type: *Heteronympha merope* Fabricius, Wallengren (= *Papilio merope* Fabricius 1775). (If not selected by the author, the type species was validly fixed by Butler, 1868: 99-100, when Butler selected *merope* Fabr. as the type of his genus *Hipparchioides* and himself rejected the latter as a synonym of *Heteronympha* Wallengren.)

Hipparchioides Butler 1867, Ann. Mag. nat. Hist. (3) 19: 125.

Type: *Hipparchioides merope* Fabr., Butler (= *Papilio merope* Fabricius 1775) (fixed by Butler, 1868: 99).

Heteronympha Wallengren 1858. Type: *Papilio merope* Fabr. (fixed by Butler 1868, Entom. mon. Mag. 4: 195).

H. merope merope (Fabricius) 1775. New Holland (Fabr.). This was one of the species undoubtedly taken during Cook's stay in Botany Bay.

H. Merope Salazar Fruhstorfer 1911

Heteronympha merope salazar Fruhstorfer 1911 in Seitz Grossschmett. Erde 9: 305. Waterhouse and Lyell 1914, Butt. Australia: 37. *Heteronympha salazar* Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. *Heteronympha merope* var. *salazar* Gaede 1931 in Strand Lepid. Catal. 43: 83. *Heteronympha merope salazar* Waterhouse 1932, What Butt. is that?: 101.

merope (nec Fabricius 1775)

Hipparchioides merope Butler 1867, Ann. Mag. nat. Hist. (3) 19: 126 (pt.). *Heteronympha merope* Kirby 1871, Synon. Catal. diurn. Lepid.: 79 (pt.). Masters 1873, Catal. diurn. Lepid. Aust.: 16 (pt.). Miskin 1891, Ann. Queensl. Mus. 1: 31-32 (pt.). Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 16 (pt.). Rainbow 1907, Guide study Aust. Butt.: 104-107 (pt.) (early stages). Froggatt 1907, Aust. Ins.: 218 (pt.). Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 121. Turner 1939, *loc. cit.*, 1938: 106.

Type Locality: Tasmania (Fruhstorfer). I designate Hobart as the type locality.

Holotype: Not known.

Distribution: Generally distributed from sea level to c. 2500 feet.

H. penelope penelope Waterhouse 1937. Barrington Tops, N.S.W.

H. Penelope Diemeni Waterhouse 1937

Heteronympha penelope diemeni Waterhouse 1937, Proc. linn. Soc. N.S.W. 62 (5/6) : 258 ♂ ♀. *Heteronympha penelope diemani* (sic) Barrett and Burns 1951, Butt. Aust. and N. Guinea: 67. *Heteronympha penelope diemeni* Tindale 1952, Trans. Roy. Soc. South Aust. 75: 25, 27.

philerope (nec Boisduval 1832)

Heteronympha philerope Masters 1873, Canal. diurn. Lepid. Aust.: 16 (pt.). Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 17 (pt.). Fruhstorfer 1911 in Seitz Grossschmett. Erde 9: 305 (pt.). Waterhouse and Lyell 1914, Butt. Australia: 39 (pt.). Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146 (pt.). Turner 1926, *loc. cit.* 1925: 121 (pt.). Waterhouse 1932, What Butt is that?: 99 (pt.). Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 106 (pt.).

Type Locality: New Norfolk near Hobart. (Waterhouse.)

Holotype ♂ and Allotype ♀: Australian Mus.

Distribution: North-west, North and Eastern coastal areas from sea level to c. 2000 feet.

H. Penelope Panope Waterhouse 1937

Heteronympha penelope panope Waterhouse 1937, Proc. linn. Soc. N.S.W. 62 (5/6): 258 ♂. Tindale 1952, Trans. Roy. Soc. South Aust. 75: 25, 27.

philerope (nec Boisduval 1832)

Heteronympha philerope Waterhouse and Lyell 1914, Butt. Australia: 39 (pt.). Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146 (pt.). Hardy 1918, *loc. cit.*, 1917: 68. Turner 1926, *loc. cit.*, 1925: 121 (pt.). Waterhouse 1932, What Butt. is that?: 99 (pt.). Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 106 (pt.).

Type Locality: Cradle Mt., Tasmania, 2000 feet. (Waterhouse.)

Holotype ♂: Australian Mus.

Distribution: Central and Western Mountain plateau from 2000 to 3500 feet, Strahan at sea level.

H. cordace cordace (Geyer) 1832. Mountain ranges of southern N.S.W. (Couchman 1954).

H. Cordace Legana Couchman 1954

Heteronympha cordace legana Couchman 1954, Pap. Proc. Roy. Soc. Tasm. 88: 74. ♂ ♀.

cordace (nec Geyer 1832)

Heteronympha cordace Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 106 (pt.).

Type Locality: Lake Leake, 1900-2100 feet.

Holotype ♂ and Allotype ♀: Hobart, Couchman Coll.

Distribution: North-eastern areas at c. 1500-2500 feet.

H. Cordace Kurena Couchman 1954

Heteronympha cordace kurena Couchman 1954, Pap. Proc. Roy. Soc. Tasm. 88: 73-74 ♂ ♀.

cordace (nec Geyer 1832)

Heteronympha cordace Hardy 1918, Pap. Proc. Roy. Soc. Tasm. 1917: 68. Turner 1926, *loc. cit.*, 1925: 121 (pt.). Waterhouse 1932, What Butt. is that?: 102 (pt.). Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 106 (pt.). Burns [1948] Mem. Nat. Mus. 15 (1947): 90 (pt.). *Heteronympha c. cordace* Barrett and Burns 1951, Butt. Aust. and N. Guinea: 67-68 (pt.).

Type Locality: Cuvier River, 2500 feet.

Holotype ♂ and Allotype ♀: Hobart, Couchman Coll.

Distribution: Western plateau from the Dee River, 2200 feet to Derwent Bridge and Cradle Mt., 2400-3000 feet.

H. Cordace Comptena Couchman 1954

Heteronympha cordace comptena Couchman 1954, Pap. Proc. Roy. Soc. Tasm. 88: 71-73. pl. 1. f. 3, 4 ♂ ♀.

cordace (nec Geyer 1832)

Heteronympha cordace Waterhouse and Lyell 1914, Butt. Australia: 40 (pt.). Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. Turner 1926, *loc. cit.*, 1925: 121 (pt.). Waterhouse 1932, What Butt is that?: 102 (pt.). Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 106 (pt.).

Type Locality: Strahan, sea level.

Holotype ♂ and Allotype ♀: Hobart, Couchman Coll.

Distribution: West and South coastal areas from Strahan to Dover, sea level to c. 500 feet.

Genus: Argynnina Butler 1867, Ann. Mag. nat. Hist. (3) 19: 165.

Type: *Lasiommata hobartia* Westwood [1851] (fixed by Butler 1868, Entom. mon. Mag. 4: 196.)

A. Hobartia (Westwood) [1851]

Lasiommata hobartia Westwood [1851] in Doubleday Genera diurn. Lepid. (2): 387 ♀. *Argynnina hobartia* Butler 1867, Ann. Mag. nat. Hist. (3): 19: 165. Butler 1868, Catal. Satyridae Brit. Mus.: 165. *Xenica hobartia* Kirby 1871, Synon. Catal. diurn. Lepid.: 76. Masters 1873, Catal. diurn. Lepid. Aust.: 15. Miskin 1891, Ann. Queensl. Mus. 1: 30 (pt.). Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 17 (pt.). Rainbow 1907, Guide study Aust. Butt.: 113-114 (pt.). text f. 71 (early stages) (nec. plate). Fruhstorfer 1911 in Seitz Grossschmett. Erde 9: 304 (nec plate). *Argynnina h. hobartia* Waterhouse and Lyell 1914, Butt. Australia: 40. pl. [40], f. 826. *Argynnina hobartia* Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. Waterhouse 1923, Proc. linn. Soc. N.S.W. 48 (1): 18 (early stages). *Lasiommata hobartia* Riley and Gabriel 1924, Catal. Type spec. Lepid. Rhop. Brit. Mus. 1: 25. *Arginnina* (sic) *hobartia* Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 82. *Xenica hobartia* Gaede 1931 in Strand Lepid. Catal. 43: 81 (pt.). *Argynnina h. hobartia* Waterhouse 1932, What Butt is that?: 119. pl. 17, f. 9. *Lasiommata hobartia* Hemming 1941, J. Soc. bibliogr. nat. Hist. 1 (11): 455. *Argynnina hobartia* Couchman 1946, Pap. Proc. Roy. Soc. Tasm. 1945: 50.

lasus

Lasiommata lasus Hewitson 1864, Trans. ent. Soc. Lond. (3) 2: 248. pl. 16, f. 5.

Type Locality: Van Diemen's Land. (Westwood.) As suggested by the name, Westwood's specimen evidently came from Hobart. I designate this the type locality.

Holotype ♀: Brit. Mus. (Nat. Hist.).

Distribution: Northern, eastern and southern areas, at altitudes from sea level to c. 2500 feet, extending westward to Derwent Bridge.

A. Tasmanica (Lyell) 1900

Xenica tasmanica Lyell 1900, Vict. Nat. 17: 110-112. pl. [2], f. [1-3] ♂ ♀. Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 17. Fruhstorfer 1911 in Seitz Grossschmett. Erde 9: 304. *Argynnina tasmanica* Waterhouse and Lyell 1914, Butt. Australia: 41. pl. 12, f. 127, 128. Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. Hardy 1918, *loc. cit.*, 1917: 68. *Arginnina* (sic) *tasmanica* Turner 1926, *loc. cit.*, 1925: 122. *Argynnina tasmanica* Tillyard 1926, Ins. Aust. and N. Zeal.: 462. pl. 43, f. 9. *Xenica tasmanica* Gaede 1931 in Strand Lepid. Catal. 43: 82. *Argynnina tasmanica* Waterhouse 1932, What Butt. is that?: 120. pl. 17, f. 10. Waterhouse 1937, Rep. Aust. and N. Zeal. Ass. adv. Sci. 23: 107. Couchman 1948, Rec. Queen Vict. Mus. 2 (2): 93-94.

Type Locality: Strahan.

Holotype ♂ and Allotype ♀: Australian Mus.

Distribution: West Coast areas from sea level to 3000 feet.

Genus: Oreixenica Waterhouse and Lyell 1914, Butt. Australia: 41.

Type: *Oreixenica lathoniella* Westwood, Waterhouse and Lyell (= *Lasiommata lathoniella* Westwood [1851]) (fixed by authors).

Gaede (1931: 167) attributes this genus to Hardy (1916) and includes as the only species *flynni* Hardy (1916), a curious error.

O. orichora orichora (Meyrick) 1885. Mt. Kosciusko, N.S.W.

O. Orichora Flynni Hardy 1916

Oreixenica flynni Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 145, 146 ♀. Hardy 1918, *loc. cit.*, 1917: 67, 68. *Oreixenica orichora flynni* Tindale 1923, Trans. Roy. Soc. South Aust. 47: 342. pl. 28, f. 4-6 ♂. *Oreixenica flynni* Gaede 1931 in Strand Lepid. Catal. 43: 167. *Oreixenica orichora flynni* Waterhouse 1932, What Butt. is that?: 118. Couchman 1946, Pap. Proc. Roy. Soc. Tasm. 1945: 50. *Oreixenica orichora* race *flynni* Barrett and Burns 1951, Butt. Aust. and N. Guinea: 51. *Oreixenica orichora flynni* Couchman 1953, Proc. R. ent. Soc. Lond. (B) 22 (5/6): 84.

orichora (nec Meyrick 1885)

Oreixenica orichora Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 122.

Type Locality: Cradle Mountain, 3000 feet (Hardy) ♀. Cradle Mountain at about 2000 feet. (Tindale) ♂.

Holotype ♀: Australian Mus. Neallotype ♂: South Aust. Mus.

Distribution: Western mountains from Cradle Mt. to Mt. Rufus, at altitudes of 2400-3400 feet.

O. Paludosa (Lucas) 1892

Xenica paludosa Lucas 1892, Proc. Roy. Soc. Queensl. (1891-1892) 8 (3): 71-73 ♂ ♀. Lyell 1900, Vict. Nat. 17: 112. *Xenica lathoniella paludosa* Fruhstorfer 1911 in Seitz Grossschmett. Erde 9: 304 (pt.).

Xenica lathoniella var. *paludosa* Gaede 1931 in Strand Lepid. Catal. 43: 82 (pt.). *Oreixenica paludosa* Couchman 1953, Proc. R. ent. Soc. Lond. (B) 22 (5/6): 73-75.

Type Locality: Near Launceston. (Lucas.)

Holotype and Allotype: Not known. When discussing this species in 1953 I showed that Lucas' description was applicable only to a female of the *latialis* or *ptunarra* pattern and must not be regarded as a synonym of *lathoniella,* as hitherto placed by authors.

The reasons then given for not accepting the specimens in the South Australian Mus. labelled "probable type" and "probable cotype" (labelled as a result of my enquiries in 1947) I believe are still unanswerable, particularly in regard to the disparity in size when compared with Lucas' description, the absence of data and the form of pinning and setting.

The exact locality remains unknown, but subsequent collecting in the western alpine areas convinces me it may still be possible to find an insect approximating Lucas' description and size, in the alpine areas between the valley of the South Esk River and the north-eastern coastline.

O. Lathoniella Lathoniella (Westwood) [1851]

Lasiommata? lathoniella Westwood [1851] in Doubleday Genera diurn. Lepid. (2): 387 ♂. *Argynnina lathoniella* Butler 1867, Ann. Mag. nat. Hist. (3): 166. pl. 4, f. 6 (neuration). Butler 1868, Catal. Satyridae Brit. Mus. 1: 165. *Xenica lathoniella* Kirby 1871, Synon. Catal. diurn. Lepid.: 76. Masters 1873, Catal. diurn. Lepid. Aust.: 15. Miskin 1891, Ann. Queensl. Mus. 1: 30 (pt.). Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 17 (pt.). Rainbow 1907, Guide study Aust. Butt.: 114-115 (pt.). *Oreixenica l. lathoniella* Waterhouse and Lyell 1914, Butt. Australia: 42. pl. [40], f. 821, 822. *Oreixenica lathoniella* Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. *Xenica lathoniella* Novickij 1923, Sborn. ent. Odd. nár. Mus. Praze 1: 60 (Fiji ! Err. det.?). *Oreixenica lathoniella* Waterhouse 1923, Proc. linn. Soc. N.S.W. 48 (1): 18 (early stages). *Lasiommata lathoniella* Riley and Gabriel 1924, Catal. Type spec. Lepid. Rhop. Brit. Mus. 1: 30. *Oreixenica lathoniella* Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 81, 122. Tillyard 1926, Ins. Aust. and N. Zeal.: 462. *Xenica lathoniella* Gaede 1931 in Strand Lepid. Catal. 43: 82 (pt.). *Oreixenica l. lathoniella* Waterhouse 1932, What Butt. is that?: 115. pl. 17, f. 2. *Xenica lathoniella* Waterhouse 1936, Proc. R. ent. Soc. Lond (B) 5 (9): 173 (note on Novickij 1923). *Oreixenica lathoniella* Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 58 (pt.), 106 (pt.). *Lasiommata? lathoniella* Hemming 1941, J. Soc. bibliogr. nat. Hist. 1 (11): 456. *Oreixenica l. lathoniella* Barrett and Burns 1951, Butt. Aust. and N. Guinea: 53-54. Couchman 1953, Proc. R. ent. Soc. Lond. (B) 22 (5/6): 73, 82, 83.

paludosa (nec Lucas 1892)

Oreixenica lathoniella paludosa Fruhstorfer 1911 in Seitz Grossschmett. Erde 9: 304 (pt.).

barnardi

Oreixenica lathoniella race *barnardi* Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 81-82.

Type Locality: Van Diemen's Land (Westwood) "the neighbourhood of Hobart" (Waterhouse and Lyell).

Holotype ♂: Brit. Mus. (Nat. Hist.).

Distribution: Northern, eastern and southern areas from sea level to 3500 feet.

O. LATHONIELLA f. MAWEENA Couchman 1953

Oreixenica lathoniella f. *maweena* Couchman 1953, Proc. R. ent. Soc. Lond. (B) 22 (5/6): 82, 83 ♀.

Type Locality: Knocklofty, Tas., 750 feet.

Holotype ♀: Hobart, Couchman Coll.

Distribution: Throughout the State, in all subspecies and at all altitudes.

O. LATHONIELLA LARANDA Waterhouse and Lyell 1914

Oreixenica lathoniella laranda Waterhouse and Lyell 1914, Butt. Australia: 42. pl. 12, f. 134: pl. [40], f. 834 ♂ ♀. *Oreixenica laranda* Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. Turner 1926, *loc. cit.*, 1925: 82, 122. *Xenica lathoniella* var. *laranda* Gaede 1931 in Strand Lepid. Catal. 43: 82. *Oreixenica lathoniella laranda* Waterhouse 1932, What Butt. is that?: 116. pl. 17, f. 3. *Oreixenica lathoniella* race *laranda* Barrett and Burns 1951, Butt. Aust. and N. Guinea: 53. *Oreixenica lathoniella laranda* Couchman 1953, Proc. R. ent. Soc. Lond. (B) 22 (5/6): 73, 82, 83.

lathoniella (nec Westwood [1851])

Oreixenica lathoniella Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 58 (pt.).

Type Localities: Zeehan. Mt. Magnet. (Waterhouse and Lyell.) The holotype and allotype are labelled Zeehan. I nominate this as the type locality.

Holotype ♂ and Allotype ♀: Australian Mus.

Distribution: Western and south-western coastal areas from Waratah to Port Davey.

O. PTUNARRA PTUNARRA Couchman 1953

Oreixenica ptunarra ptunarra Couchman 1953, Proc. R. ent. Soc. Lond. (B) 22 (5/6): 77-78, 81, 82, 83, 84 ♂ ♀. Couchman 1954, Pap. Proc. Roy. Soc. Tasm. 88: 75. pl. 1, f. 5, 6.

Type Locality: Miena, 3300 feet.

Holotype ♂ and Allotype ♀: Hobart, Couchman Coll.

Distribution: Great Lake area at altitudes above 2700 feet.

O. PTUNARRA ROONINA Couchman 1953

Oreixenica ptunarra roonina Couchman 1953, Proc. R. Ent. Soc. Lond. (B) 22 (5/6) : 78-79, 81, 82 ♂ ♀.

Type Locality: Mike Howes Marsh, 2100 feet.
Holotype ♂ and Allotype ♀ : Hobart, Couchman Coll.
Distribution: Restricted to the type locality, specimens from Old Man's Head, 3350 feet; Interlaken and the Steppes, 2700 feet, are referable to *pt. ptunarra.*

O. PTUNARRA ANGELI Couchman 1953

Oreixenica ptunarra angeli Couchman 1953, Proc. R. ent. Soc. Lond. (B) 22 (5/6) : 79-80, text f. 2; 80 (early stages) ♂ ♀.

Type Locality: Lake Leake, 1800-2100 feet.
Holotype ♂ and Allotype ♀ : Hobart, Couchman Coll.
Distribution: Lake Leake area at c. 2000 feet.

Genus: GEITONEURA Butler 1867, Ann. Mag. nat. Hist. (3) 19: 164-165.
Type: *Satyrus klugii* Guérin-Méneville [1830] (fixed by Butler 1868, Catal. Satyridae Brit. Mus.: 166).
Xenica (Auctorum nec. Westwood [1851])

G. KLUGII KLUGII Guérin-Méneville [1830]

Satyrus klugii Guérin-Méneville [1830] in Duperrey Voy. Coquille (Ins.) Atlas: pl. 17, f. 2 ♀. *Xenica klugii* Masters 1873, Catal. diurn. Lepid. Aust.: 15. Miskin 1891, Ann. Queensl. Mus. 1: 30. Waterhouse 1903, Mem. N.S.W. Natur. Club 1: 17. *Xenica kluggi* Rainbow 1907, Guide study Aust. Butt.: 110, 112-113. pl. 3, f. 1 (as *Xenica klugii*) *Xenica klugi* Fruhstorfer 1911 in Seitz Grossschmett. Erde 9: 304. pl. 93c (5). Waterhouse and Lyell 1914, Butt. Australia: 44. pl. 12, f. 137, 138. [40], f. 825. Hardy 1916, Pap. Proc. Roy. Soc. Tasm. 1916: 146. Waterhouse 1923, Proc. linn. Soc. N.S.W. 48 (1) : 19 (early stages). Turner 1926, Pap. Proc. Roy. Soc. Tasm. 1925: 122. Tillyard 1926, Ins. Aust. and N. Zeal.: 462. *Xenica klugii* Gaede 1931 in Strand Lepid. Catal. 43: 81-82. *Xenica klugi* Waterhouse 1932, What Butt. is that?: 104. pl. 15, f. 11. Waterhouse 1937, Rep. Aust. and N. Zeal. Ass. adv. Sci. 23: 107. Waterhouse 1937, Proc. linn. Soc. N.S.W. 62 (5/6) : 256. Turner 1939, Pap. Proc. Roy. Soc. Tasm. 1938: 106. *Geitoneura klugii* Couchman 1946, *loc. cit.*, 1945: 51. *Geitoneura klugi klugi* Barrett and Burns 1951, Butt. Aust. and N. Guinea: 60-61 (early stages).

Satyrus singa Boisduval 1832 ♂ and *Satyrus philerope* Boisduval 1832 ♀ (nec ♂) are synonyms referable to the form found in the Port Jackson area.

Type Locality: Blue Mts., N.S.W. (Waterhouse 1937).
Holotype ♀ : Not known.
Distribution: Throughout the State from sea level to 2500 feet.

There has been some doubt regarding the date of appearance of Guérin's plate 17, which Guérin himself, on p. 271 of the text, shows as published in Livraison 19, in November-December 1830. Mr. A. Musgrave, to whom I am indebted for this information, proposes to publish a short note on this question.

Butler 1868, Entom. mon. Mag. 4: 196).
GEITONEURA Butler 1867. Type: *Satyrus klugii* Guérin-Méneville [1830] (fixed by

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NOTES ON TASMANIAN MOSSES FROM RODWAY'S HERBARIUM: VII.

By

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Family NEMATACEAE

Mr. J. H. Willis's outstanding discovery of a scrap of what is probably the New Zealand *Ephemeropsis trentepohlioides* (Ren.) Sainsb. amongst some mosses which he had collected near Mt. Field, National Park, Tasmania, is recorded by him in *Nature* (Nemataceae, a Moss Family new to Australia; 1953; 172: 127). This extraordinary plant is one of the wonders of the bryological world. The gametophyte is reduced almost entirely to a branched protonema, but this primitive structure is associated with a highly developed sporophyte, consisting of a relatively long seta and a capsule with a double peristome, which discloses unmistakable affinity with Hookeraceous mosses. It is probable that this association of such a primitive gametophyte with a highly developed sporophyte can only be explained on the assumption that the former is a reduction or reversion to the primeval gametophyte of the mosses. The plants are on a very small scale, the capsule often being less than 0·5 mm. long, the seta to 2 mm. The protonemal gametophyte forms a dense alga-like mat on twigs and is practically impossible to find unless fruit is present. Even then it is only too likely to be overlooked. Mr. Willis's material was too scanty to allow dissection, but I think that it can safely be referred to the New Zealand species. The only other species, *E. tjibodensis* Goeb., has an East Indian distribution. It shows some differences from the Australasian plant.

Family HOOKERIACEAE

This family, founded by Brotherus, supercedes Lindberg's Pterygophyllaceae which appears in Rodway's work. The plants have soft stems and leaves, the latter being either evenly arranged round the stem (in *Sauloma* and *Daltonia*) or complanately, with the lateral leaves rather asymmetrical (in *Eriopus, Distichophyllum* and *Pterygophyllum*). The flattened stems in the latter group sometimes simulate hepatics, especially where the plants are terrestrial in damp shady stations. In *Eriopus* the nerve is either lacking or shortly double, whilst in *Distichophyllum* and *Pterygophyllum* it is single, though sometimes forked at the apex.

Sauloma H. f. & W. A. small Australasian genus containing 2 or 3 species. Distinguishable from *Daltonia* by the nerveless unbordered leaves.

Sauloma tenella (H. f. & W.) Mitt. The plants are soft and glossy, whitish-green or yellow. The leaves are closely imbricated, lanceolate or oblong-lanceolate, nerveless, with entire and variably recurved margins, and lax, narrowly linear-rhomboid cells. The small capsule, exserted on a seta about 1 mm. long, is contracted below the mouth when dry.

Daltonia Hook. & Tayl. The genus is widely distributed in warm regions and has many published species, though probably a large number will eventually become synonyms.

Daltonia augustifolia Dz. & Mb. Syn. *D. pusilla* H. f. & W. An East Indian moss with which Fleischer, in Musci von Buitenzorg, considers the Tasmanian plant to be conspecific. From what I have seen of the respective species I would not consider them to be satisfactorily separable. Fleischer and Dixon were both inclined to the view that the East Indian moss and *D. pusilla* are scarcely distinct from the Northern *D. splachnoides* Hook. & Tayl., and I understand that this is also Willis's opinion. *D. angustifolia* grows in small dense tufts on bark. Rodway's statement that the habitat is sometimes fern-leaves is interesting in view of the fact that so few of the Australasian mosses are epiphyllous, and also that epiphyllous forms of this and other species of *Daltonia* occur in the tropics. The leaves are symmetrical and closely imbricated round the stem, narrowly lanceolate, nerved to some distance below the apex, and bordered with several rows of narrow cells. The cells at the insertion are isodiametrical and reddish brown. The seta is variably rough in its upper part.

Eriopus (Brid.) C. Mull. The characters here, in addition to the nerve structure, are the strongly bordered leaves and the hairiness or papillosity of the seta.

Eriopus apiculatus (H. f. & W.) Mitt. The leaves are stoutly bordered and practically entire and nerveless. Rodway is in error in describing the seta as strigose; it is usually lowly papillose, though sometimes the papillae may be large and spiky.

Eriopus flexicollis (Mitt.) Jaeg. Syn. *Eriopus tasmanicus Broth.*??

There is an undoubted specimen of this New Zealand species, formerly ranked as endemic, in Rodway's collection. It is from Mt. Wellington, and is labelled "Eriopus". His description of *E. tasmanicus* could apply to *E. flexicollis*, though Dixon (in the Studies) suspects that the former may be referable to the New Zealand endemic *E. cristatus*. The two New Zealand species have much in common, but the upper cells in *E. cristatus* are wider than in *E. flexicollis*, 50-60 μ as against 25-40 μ. The specimens in Rodway's herbarium named as *E. tasmanicus* are referable to *E. apiculatus*.

Distichophyllum Mitt. The Tasmanian and New Zealand species form a rather heterogeneous group, due to the presence in both countries of *D. macrocarpum* which, unlike the others, has unbordered leaves. The plants have a smooth seta, and the calyptra is fimbriate at the base.

Distichophyllum rotundifolium (H. f. & W.) Broth. This is closely related to the next, the separating characters of the present species being the small rounded leaves with a short, stout apiculus and denticulate

margin. From what I have seen of the New Zealand plants the habitat is usually damp rotten logs, whereas in Tasmania it seems to be mostly wet rock.

Distichophyllum crispulum (H. f. & W.) Mitt. The branches are more flattened than in *D. rotundifolium*, the leaves widely oval-oblong, less crisped when dry, nearly entire, and with a longer and slenderer point. The areolation is similar and the fruiting characters are the same.

Distichophyllum pulchellum (H. f. & W.) Mitt. Syn. *D. amblyophyllum* (H. f. & W.) Mitt. This is more robust than either of the preceding, with flattened stems and leaves flaccid and densely imbricated. The latter are broadly spathulate, entire, rounded at the apex, and either with or without a very short apiculus. There is a thin pale border of long and narrow marginal cells. The variety *parvirete* Sainsb., which I published on New Zealand material (Rev. Bry. et Lich., 16 : 47), has the upper leaf-cells much smaller, 7-10 μ in diameter as against 12-20 μ. There are two Mt. Wellington collections of this variety in Rodway's collection, one made by Weymouth and determined by Brotherus as *D. crispulum*, and the other collected by Rodway and labelled *D. pulchellum*. So far as *D. amblyophyllum* is concerned, I do not think that it is anything more than a robust form of the present species, with the leaf apex usually non-apiculate. I have found that the presence or absence of the apiculus is inconstant throughout, sometimes even in a single stem.

Distichophyllum microcarpum (Hedw.) Mitt. This robust species is sharply distinguished by the absence of a border, the rounded leaf apex, and the small upper and outer cells which strongly contrast with the larger central ones. As Rodway mentions, the stems become greatly elongated when growing in mats on wet rock walls.

Pterygophyllum Brid. Of the three species mentioned by Rodway as occurring in Tasmania two, i.e., *P. denticulatum* and *P. nigellum*, are given in the Studies as synonyms of *P. dentatum* (H. f. & W.) Mitt., and it is there pointed out that the specific name "denticulatum" is merely a slip. The third species, *P. Hookeri*, is not known to me and is not present in the collection, but from Rodway's description it would appear to be a robust form of *P. dentatum*, probably referable to the var. *robustum* (H. f. & W.) Dix. From what I have seen of the Tasmanian plants, the leaves seem to be more strongly dentate than they are in the New Zealand race. This moss can usually be recognised in the field by the blackish leaves which are distant and strongly crisped when dry. They do not soak out readily.

Family HYPOPTERYGIACEAE

This is the equivalent of Rodway's family Lophidiaceae, except that the genus *Rhacopilum* is excluded as having no real affinity with the group. The plants differ from all other Tasmanian mosses in having differentiated leaves (amphigastria) produced on the ventral side of the flattened branches. The lateral leaves, in two rows, are complanate. The presence in Tasmania of the New Zealand monotypic *Catharomnion* is doubtful, according to Rodway, there being no specimens in any

collection available to him. The plant is recognisable at once by the ciliate leaf margins. The bristles which Rodway mentions as being mixed with the leaves are in fact reduced leaves, and are properly treated by the Musci as amphigastria. Of the remaining Tasmanian genera, *Lopidium* has stems branched pinnately almost to the base, whereas in *Hypopterygium* the branching is in a suborbicular terminal frond with distant stipe leaves, and in *Cyathophorum* the stems are nearly always simple, rarely singly and dichotomously branched.

Lopidium concinnum (Hook.) Fleisch. Syn. *Lopidium pallens* H. f. & W. The stems here are usually not more than half the length (10-12 cm.) given by Rodway. The fronds are soft, pale and dull, ovate-oblong in outline and pinnately branched, the branches being sometimes rebranched. In the Studies the genus (which is correctly spelt as given here) is not kept apart from *Hypopterygium*, but I think that Fleischer is correct in recognising it as distinct. The habit of growth, leaf-shape, areolation, absence of cilia, &c., are characters that seem to justify generic rank.

Hypopterygium novae-seelandiae C.M. All the Tasmanian plants that I have seen of this would belong to the var. *nudicaule* Dix. (Studies, p. 295), which deviates in having non-tomentose stems. This character, however, is also given by him as helping to distinguish the Pacific *H. rotulatum* (Hedw.) Brid. which occurs in New Zealand and to which a specimen in the collection, from Macpherson Range sub. nom. *H. viridulum* Mitt., seems to be referable. The differences between the two species are rather elusive, being founded on variations in habit, position of the leaves when dry, strength of their marginal toothing and of the nerve, &c. The amphigastria in *H. novae-seelandiae* are small, suborbicular and long apiculate.

Cyathophorum bulbosum (Hedw.) C.M. This handsome moss can be placed at a glance by the narrow undivided fronds, sometimes attaining 20 cm., with large lateral leaves and small orbicular amphigastria. The setae are almost sessile and are produced on the ventral side of the stem. The var. *minus* of the Flora Antarctica appears in Rodway's work as *C. densirete* Broth. It is a small form which, according to the Flora Antarctica, has the leaves more acute and distant than they are in the type. Brotherus distinguishes it by the denser areolation and the very short nerve. The Studies discusses the plant and points out that the length of the nerve is very variable, and that, throughout the plants, there is no constant correlation between small stems and small leaf-cells. This is my own experience, and I fully agree with the statement in the Studies that the limits of the variety are difficult to define.

Family THUIDIACEAE

The only Tasmanian genus is *Thuidium* Bry. eur., where the stems are 1-2-3-pinnate, with numerous paraphyllia, and the leaves are dimorphous, singly nerved, with uniform papillose cells.

Thuidium furfurosum (H. f. & W.) Jaeg. Syn. *T. unguiculatum* H. f. & W.; *T. Stuartii* C.M. This very common and variable ground

moss is nearly always of a yellowish tint. The branching is irregularly bi-pinnate, the branch leaves being imbricated and catenulate when dry, with their tips strongly incurved. The stem-leaves are widely triangular-lanceolate and finely acuminate, the branch-leaves ovate-cordate and finely or bluntly pointed. I reduced *T. sparsum* (H. f. & W.) Jaeg. to a variety *sparsum* in Rev. Bry. et Lich., 21 : 223 (*Critical New Zealand Mosses*). This is a very slender form, with the branch leaves blunt and the cells small and obscure. Intermediates between the variety and the type form are numerous and perplexing. Rodway mentions the absence of paraphyllia on the ultimate branches as being a character to distinguish the present species from *T. laeviusculum*. This may be a sufficient test, but I think that in doubtful cases the character of the ramuline leaves, as given in the Studies, is preferable.

Thuidium laeviusculum (Mitt.) Jaeg. The coloration is usually green, and the plant favours a moist and shaded habitat. The stems are arched and rooting at the tips, with the primary branches forming rather distant and elegant flattened fronds. As the Studies mentions, the branch leaves are imbricated and scarcely altered when dry, with their tips not incurved but erect and parallel to the branch, and with the nerve cristate at the back.

Family LESKEACEAE

A number of genera, including *Thuidium*, were formerly included in this family, but the only Tasmanian genus is now *Pseudoleskea* if the two families are treated as separate. In this genus the branching is irregular, the paraphyllia (in the Tasmanian species) absent, and the stem leaves little differentiated from the branch leaves.

Pseudoleskea imbricata (H. f. & W.) Broth. A slender moss, with crowded curved branches which are terete and julaceous when dry, and of a brown colour. It is found in New South Wales, Victoria and New Zealand. There are no specimens in Rodway's collection, and his description of the plant is misleading and possibly founded on a mistake in identification. The leaves are given as being 1·5 mm. long, though they are seldom more than half that length, and the margins are described as revolute except towards the apex, whereas they are plane or only slightly recurved at the base. The cells are stated to have prominent and nodulose papillae, but I have not seen them distinctly papillose. Moreover, there is no mention of the julaceous, terete, dry stems, which are certainly a striking character. I presume, however, that the species is indigenous in Tasmania, for it is so treated in the Flora Tasmanica, the Musci and the Studies.

NOTES ON TASMANIAN MOSSES FROM RODWAY'S HERBARIUM: VIII

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Family Amblystegiaceae

These are hypnoid, hygrophilous mosses with irregularly or pinnately branched stems. The leaves are symmetrical and singly nerved, with rather wide cells which are not inflated at the leaf base. The operculum is shortly conical or apiculate. In Rodway's main work the Tasmanian mosses which belong to this family are those included by him in the genus *Campylium,* but referable in the Musci to *Cratoneuropsis* and *Drepanocladus.* In his *Additions to the Tasmanian Flora* (Papers, &c., Roy. Soc. of Tasmania; 31st Decr. 1915) a new species of *Amblystegium* is added.

Cratoneuropsis relaxa (H. f. & W.) Broth. Syn. *Campylium relaxum* (H. f. & W.) Broth., *C. decussatum* (H. f. & W.) Broth., *C. molle* Broth. I have little doubt that the three species of *Campylium* given by Rodway are referable to this variable moss. He does not mention the densely set, squarrosely spreading leaves which are a strong character. They are ovate-acuminate, with the apex reflexed. Astonishing extremes in the size and robustness of the plants are accompanied by variation in the length of the nerve and in the degree of denticulation of the leaf margins, but my study of New Zealand material has convinced me that there is no satisfactory correlation of these characters. The Studies (pg. 321) refers to *C. molle* as being perhaps an extremely slender form derived from either of the other two species in the above synonymy. The specimen of it in Rodway's collection appears to be a form of the present species. The Studies refers to *C. molle* as being ined., but Rodway's description of it would no doubt constitute valid publication.

Drepanocladus (C.M.) Roth. The leaves here are more or less falcate-secund, strongly nerved and with the alar cells normally inflated so as to form distinct auricles. The upper cells are rather narrow. Two species are given by Rodway in his main work, i.e., *D. fluitans* (Hedw.) Warnst. and *D. brachiatus* (Mitt.) Dixon. The former is a circumpolar moss widely distributed in both northern and southern hemispheres, and the latter is probably an antarctic form of the type species, *D. aduncus* (Hedw.) Moenk., which has a similar distribution. *D. brachiatus* has poorly developed alar cells, but in other respects conforms to the type and is connected with it, at any rate in New Zealand, by intermediate forms. Both species are extremely variable. They cannot be separated from each other by Rodway's descriptions, which moreover are misleading

in that the leaf margin in *D. fluitans* is stated to be entire, whereas some denticulation, usually at the apex, is always apparent in some of the leaves. *D. aduncus* is separable by the entire and broader leaves, which are decurrent at the auricles and cause the line of insertion to be curved, not straight as in *D. fluitans*. The cells are shorter and wider than they are there. In Rodway's Additions, cited above, *D. sendneri* Warnst. is added to the Tasmanian flora, but this species is considered by Dr. F. E. Wynne, whose papers on this difficult genus should be consulted, to be synonymous with *D. aduncus*. Another circumpolar species, *D. uncinatus* (Hedw.) Warnst., which occurs in montane regions of New Zealand, is quite likely to be found in Tasmania. It is distinguished by the plicate leaves with a serrulate acumen. It is a mesophyte and is normally corticolous.

Amblystegium Bry. eur. The plants here are slender, with small leaves which are straight or weakly falcate. The cells are short and wide, those at the base quadrate or rectangular, but not forming inflated auricles. In Rodway's paper above referred to an endemic species, *A. austro-serpens* Broth., is added to the flora. The locality given is " in stream at mouth of River Huon ". I have not seen the plant and there is no mention of it in the Musci, but from the description I have little doubt that it is referable to the northern *A. serpens* (Hedw.) Bry. eur. which occurs in New Zealand and which I have seen from Heard and Macquarie Islands. It is a very slender plant, more or less hygrophilous, with small, spreading, ovate-acuminate leaves, less than 1 mm. long, which are singly nerved to about mid leaf. Other New Zealand representatives of boreal species of this family are *Cratoneuron filicinum* (Hedw.) Broth., *Leptodictyum riparium* (Hedw.) Warnst. and *Campylium polygamum* (Bry. eur.) Bryhn., all of which are hygrophytes and could be sought for in Tasmania with prospects of success.

Family Brachytheciaceae

Corticolous or terrestrial plants, rarely hygrophilous, with symmetrical leaves evenly arranged round the stem, sometimes plicate, and with the margins mostly denticulate. Nerve usually failing well below the apex, and often weak. Cells elongate and smooth, somewhat differentiated at the base, but not inflated. Seta smooth or papillose. Operculum blunt or with a long beak. Peristome hypnoid and perfect.

Brachythecium B. & S. The distinguishing characters here are the occasional plication of the leaves, a rather pronounced differentiation of the cells at the leaf base, and a conical operculum. The seta may be smooth or papillose, or partially one or the other, and as this papillosity is an important specific character it goes without saying that the identity of barren plants is often very difficult, and sometimes impracticable. The plants are frequently found in damp or wet stations. The specimens that I have seen from the collection are few and mostly imperfect, so I am unable to add much to Rodway's accounts of the respective species. *B. paradoxum* is distinct in the strongly falcate-secund plicate leaves, but the three other species he mentions are often difficult to deal with. In *B. salebrosum* the leaves are distinctly plicate and are narrower and longer acuminate than in *B. rutabulum*. In the latter the plants are

more robust and less glossy, the leaves are less plicate and the seta is rough throughout, whereas in *B. salebrosum* it is quite smooth. According to Dixon's Handbook, *B. campestre* B. & S. is practically indistinguishable from *B. salebrosum* except by the roughness of the seta in its upper part. So far as I know, *B. campestre* is not mentioned by anyone, except Rodway, as having been reported in the southern hemisphere. The two barren plants which I have seen from the collection seem to be referable to *B. salebrosum* and *B. rutabulum* respectively, so far as can be judged by the vegetative characters. Rodway states that *B. salebrosum* is not in any available Tasmanian collection, but it is given as a Tasmanian moss in the Musci and Studies, and in any event *B. campestre* is very close to it.

Rhynchostegium Bry. eur. A weak genus, distinguishable from *Eurhynchium* principally by the smooth seta. The operculum is long rostrate, not conical as in *Brachythecium*, and the leaves are more spreading and without plicae. Rodway adds a strong nerve as another character, but I do not think that this is a reliable criterion. Dixon (Studies, pg. 327) reduces *Hypnum aristatum* to a synonym of *Rhynchostegium laxatum* (Mitt.) Par. He considers that it is best separated from *R. tenuifolium* by the leaf cells being shorter and less tapered at the ends than they are there. Other characters, such as the degree of denticulation of the leaf margin, the habit of the plants, the leaf shape, &c., are given in the literature, but I have not always found these distinctions to be constant, and although the areolation is usually a safe guide it must, I think, be conceded that some of the plants can only be considered as intermediate between the two species.

Rhynchostegiella (Bry. eur.) Limpr. Plants as in *Rhynchostegium* but very small and slender. Seta rough in the Australasian species.

Rhynchostegiella muriculata (H. f. & W.) Broth. This has an Australasian distribution. It grows in soft dense tufts on bark, the stems being short, slender and irregularly pinnate. The leaves are up to 1 mm. long, acuminate and subpiliferous, with a slender short nerve and with cells usually lax, scarcely differentiated at the base. The rough seta will distinguish it from *Rhynchostegium laxatum*.

Rhynchostegiella cucullata (Mitt.) Dix. Syn. *Hypnum convolutifolium* Hpe. Separable from the preceding by the obtuse or bluntly acute branch leaves and the short opaque cells which are subquadrate at the base. This rare Victorian moss is very slender and small. The only Tasmanian record appears to be the Latrobe locality mentioned by Rodway. The specimen in his herbarium was collected by Weymouth, No. 242, March 1893, at Latrobe Waterworks, River Mersey. Dixon reduced the later published *Hypnum convolutifolium* to synonymy in Journ. Bot. 62: 234 (1924). The New Zealand *R. novae-zealandiae* Dix., which is also a very slender small plant, is rather closely related, but has acute and finely acuminate leaves, with longer cells. In both the spores are large, 18-28 μ in the New Zealand plant.

Eurhynchium Bry. eur. This genus, as treated here, is delimited according to Dixon's treatment in the Studies. (p. 323). The seta is rough, and the leaves are often dimorphous and usually somewhat plicate. The nerve occasionally ends dorsally in a spicule. In Rodway's work the plants are placed in the genus *Oxyrrhynchium*.

Eurhynchium praelongum (Hedw.) Hobk. This is a widely distributed moss in the northern hemisphere, but the only southern records are from New Zealand. The only Tasmanian specimen that I have seen or heard of was collected at Lymington, near Cygnet, Huon River, by R. N. Farquhar. It is barren but is certainly this species. I have not received particulars of the surroundings and so am unable to venture an opinion as to the possibility of the moss having been introduced. In New Zealand a number of records are from artificial surroundings. *E. praelongum* is easily recognised by the pronounced dimorphism of the leaves, those of the stem being widely triangular-cordate, long acuminate and with the acumen squarrosely recurved, whilst the branch leaves are much narrower, lanceolate and gradually tapering.

Eurhynchium asperipes (Mitt.) Dix. This appears in Rodway's work as a synonym of *Hypnum remotifolium,* with Mitten erroneously given as the author; but Dixon established (Studies, p. 226) that there are two mosses thus named, one of which is the South American *H. remotifolium* Grev., whilst the other is the plant of the same name in the Flora Novae-Zealandiae and Hooker's Handbook, and further that it is this latter which is identical with, and a synonym of, the present species. The only specimen named as *H. remotifolium* that I have seen from the collection is referable to *E. austrinum,* so I am not familiar with the Tasmanian plant. The leaves in *E. asperipes* are imbricated all round the stem and are rigidly divaricate when dry, with their upper parts bent inwards. In appearance the stem or branch is somewhat catenulate. The leaves are widely cordate-ovate and suddenly and finely acuminate. The cells are linear-rhomboid or linear-fusiform, somewhat laxer at the leaf base.

Eurhynchium austrinum (H. f. & W.) Broth. A robuster plant than *E. asperipes,* with erecto-patent leaves little altered when dry, sometimes vaguely plicate, rather shortly acuminate. Another difference is in the habitat, the present species being markedly hygrophilous and often aquatic.

Family Plagiotheciaceae

This is treated in the Studies as a subfamily of Hypnaceae. It is not a satisfactory group and the genera have been shifted about by systematists without agreement being reached. The distinguishing characters are the more or less complanate habit, the glossy appearance, leaves often asymmetrical, weakly nerved or nerveless, with mostly narrow smooth cells, with or without differentiated alar cells. The peristome is double and normal. The genera represented in Tasmania are *Plagiothecium, Isopterygium* and *Catagonium.*

Plagiothecium denticulatum (Hedw.) Bry. eur. The Studies gives *P. lamprostachys* Hpe. as a synonym of this widely spread northern species. It is recognisable by the glossy, green, complanate leaves, broadly ovate and somewhat asymmetrical, the short and obscure double nerve and the lax basal cells. Some forms of *Rhynchostegium tenuifolium* with complanate leaves are rather similar in gross appearance, but the leaves there are symmetrical, more sharply pointed, the nerve is single and the alar cells only slightly differentiated. Moreover, the operculum in the *Plagiothecium* is conical, not rostrate.

Isopterygium Mitt. The areolation differs from that of *Plagiothecium* in being narrower and practically unchanged at the leaf base. The Tasmanian species are much smaller plants, and the habit of the common *Isopterygium limatum* is entirely different, the leaves there being usually secund and strongly curved. They are gradually tapered from a very broad straight base to a fine, sometimes almost piliform point. It is noteworthy that *I. limatum* is evidently plentiful in Tasmania and Stewart Island, but rare in the main islands of New Zealand.

Isopterygium acuminatum Bosw. The Musci places this in the same group as the foregoing, and from Rodway's description, which accords with what I have seen of the original material in his collection, it differs from *I. limatum* in the straight and more or less complanate leaves with piliferous apices. It is a puzzling plant and its rediscovery would be welcome.

Catagonium politum (H. f. & W.) Dus. In Tasmanian specimens that I have seen of this very variable moss, there is no development of slender or flagelliform branches as often occurs in the New Zealand plant. This would account for the fact that in Rodway's description there is no mention of such branches, nor of their leaves tending to become more distant and to be narrowed to a fine long point, instead of ending, as they normally do, in a short recurved mucro.

Family SEMATOPHYLLACEAE

The Australasian genera of this large family form a group of mosses of small or medium size with lanceolate, falcate-secund and nerveless leaves and mostly smooth cells which are inflated and hyaline at the angles. The Tasmanian genera are *Acanthocladium* and *Sematophyllum* (formerly *Rhaphidostegium*). The former is represented by *A. extenuatum*, where the leaves are hair-pointed, the cells sporadically papillose and the operculum conical, and the latter by several species where the hair-point is lacking, the cells smooth and the operculum long-beaked.

Acanthocladium extenuatum (Brid.) Mitt. The robust habit, oblong piliferous leaves and enlarged vesicular alar cells are very distinctive. The seriate papillae on the leaf cells, which seem to have been first observed by Rodway, are often conspicuous but are by no means constant.

Sematophyllum Mitt. The species are difficult to delimit, and Rodway recognises this in presenting his key. The Studies' treatment is invaluable for the student of the Tasmanian plants since these all occur in New Zealand. The following key takes no account of the serrulation of the leaf margin, as I have not found this character to be very helpful.

Key to the Species

1.	Robust rupestral plants with wide, not finely subulate leaves	2.
	Plants slender and corticolous with narrowly subulate leaves	3.
2.	Hygrphilous, alar cells inflated	4. tenuirostre
	Mesophytes; on maritime rocks; alar cells incrassate, not inflated	5. homomallum
3.	Leaves falcate and curved downwards	4.
	Leaves straight and pointing upwards	3. contiguum
4.	Branches obtuse; seta smooth; plants autoicous	1. amoenum
	Branches usually cuspidate; seta roughened at apex; plants dioicous	2. leucocytus

1. *Sematophyllum amoenum* (Hedw.) Mitt. Syn. *Rhaphidostegium calliferum* Hpe. & Geh.; *R. callidioides* Hpe. & C.M.; *R. cyparioides* (Brid.). A small and common moss which forms dense patches on rotting logs. There is a superficial likeness to small forms of *Hypnum cupressiforme* where, as here, the leaf lacks a nerve, but in the present species the alar cells are hyaline and inflated and the operculum has a long subulate beak. The seta and capsule vary in length, and no doubt this is responsible for the creation of several synonymous species. *S. amoenum* is a widely spread Australasian moss. It is a free fruiter.

2. *Sematophyllum leucocytus* (C.M.) Jaeg. Syn. *Hypnum cerviculum* H. f. & W. Vegetatively there is a resemblance to some forms of the preceding. Fertile plants are recognisable by the slight roughness of the seta in its upper part. The capsule is larger than in *S. amoenum* and is ringed at the base.

3. *Sematophyllum contiguum* (H. f. & W.) Par. This is usually separable without difficulty by the pale whitish colour and by the leaves which are very narrow, secund and straight, or nearly so. In this and the two preceding species the areolation is practically the same, the cells being narrowly linear, with pointed ends, and the angle cells being large, hyaline and inflated. Rodway treats this species as a synonym of *Rhaphidostegium crassiusculum* (Brid.), but Dixon (Studies, p. 311) doubts whether the two mosses are identical.

4. *Sematophyllum tenuirostre* (Hook.) Dix. Nearly all the specimens I have seen from the collection are sub nom. *Rhaphidostegium Jolliffii*, and it would appear from these determinations and from Rodway's remarks and key to the species that he failed to recognise the differences between this species and *S. amoenum*. Normally *S. tenuirostre* is a much more robust plant. The branches are cuspidate and the leaf acumen shorter and broader. The perichaetial bracts have shorter points and the spores are larger, 14-20 μ. The plants are rupestral and hygrophilous.

5. *Sematophyllum homomallum* (Hpe.) Broth. This species is distinguishable by the robust, golden-brown, glossy patches which seem to be confined to maritime rocks. The leaves are all secund and the alar cells differ from those in the other species in being orange-yellow and incrassate, not at all inflated.

Family Hypnaceae

The mosses of Mitten's *Stereodon* which are cited by Rodway as of that genus are usually now assigned to the genus *Hypnum* as limited by Fleischer. The type species, *H. cupressiforme* Hedw. is one of the most common and most variable mosses in the world. Typically it is a fairly robust plant with irregularly branched stems. The leaves are imbricated and falcate-secund, nerveless or practically so, and usually entire and with plane margins. The cells are smooth, narrowly linear-vermicular, except for those at the angles which form an area of dark, small, subquadrate cells that are neither hyaline nor inflated. The capsule is usually suberect and the peristome is perfect. The operculum is conical, acute or shortly beaked. As Dixon mentions in his Handbook, the prominent characters of distinction are the rapidly acuminate leaves and the area of small, opaque, angular cells. Of the six remaining species cited by Rodway, *Hypnum Mossmanianum* is reduced to *H. cupressiforme* in the Studies, whilst *H. chrysogaster* has been proposed as a variety by myself (Rev. Bry. et Lich., 21: 224). *H. Walterianum,* to judge by the specimens so named in the collection, is referable to the var. *filiforme* (Brid.), which is an extreme slender form. I have not seen *Stereodon Nelsoni* which is doubtfully included by Rodway in the genus. So far as *S. flagelliramus* is concerned, the two specimens in the collection (Weymouth 196, Hobart Rivulet, and Rodway 248, April 1917, Wedge Bay), which presumably are correctly named as this plant, are both flagelliferous forms of *Acanthocladium extenuatum* which occur at Waihau Bay, Bay of Plenty, North Island, New Zealand. There are two gatherings of *H. cupressiforme* which I think must be attributable to the var. *lacunosum* Brid. (i.e., var. *elatum* B. & S.). They are Weymouth 199, Circular Head and Rodway, Mowbray, near Launceston. This variety is characterised by the tumid julaceous stems and branches, and by the wide imbricated leaves with only their tips falcate. It is noteworthy that whereas in New Zealand the var. *filiforme* is a very shy fruiter, there are several Tasmanian specimens in Rodway's herbarium in mature fertile condition.

VARIABILITY OF ANNUAL RAINFALL IN TASMANIA

By

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(With Two Text Figures)

Abstract

The distribution of average relative variability of average annual rainfall in Tasmania is determined from computed values and discussed. An evaluation is made of the departure of relative variability in Tasmania from the world mean for the variability of all places with the same average rainfall. It indicates that most of the settled areas exhibit a variability greater than the average for regions with similar average rainfall. A tentative comparison of Tasmania with the British Isles, British Columbia, and the south island of New Zealand suggests that in general the relative variability of annual rainfall in Tasmania is also greater than that experienced in some other regions having similar types of climate.

Previous Studies

Although in the importance of annual rainfall to human activity variability ranks second only to average amount, no detailed study has hitherto appeared of rainfall variability in Tasmania. Several Australian studies have encompassed Tasmania, but these have selected so few Tasmanian stations that little emerges concerning areal differentiation. The earliest and perhaps most frequently cited map is that of Griffith Taylor (1918) : it shows average relative variability over a 20-year period for five Tasmanian stations, all of which are coastal, and represents the entire island as having a mean deviation of less than 20 per cent. This map has been reproduced in later works not only by Taylor (1920, 1940) but also by Wadham and Wood (1950), and has been revised without modification of Tasmania by Leeper (1949). Another much-cited map is that by Barkley (1931), which employs standard deviation instead of mean deviation, making the percentages some 25 per cent greater than Taylor's. Moreover, by using district instead of station records, Barkley tends to underestimate variability, so that in general Taylor's map is preferable (Leeper, 1945). Nevertheless, despite this limitation, Barkley's map has been perhaps the most detailed and significant for Tasmania to date, though it contains substantial inaccuracy, particularly in the Midlands. McBride (1947) has presumably generalized Barkley's map, selecting for Tasmania only the 20 per cent isopleth, but neither the source of her map nor its measure of variability is disclosed. Loewe (1948) has applied Maurer's variability index to Miena and six coastal stations in Tasmania, but his maps of Australia are neither detailed for Tasmania nor readily comprehensible (Longley, 1952). Andrews (1932) in his discussion of rainfall reliability in Australia omits Tasmania altogether.

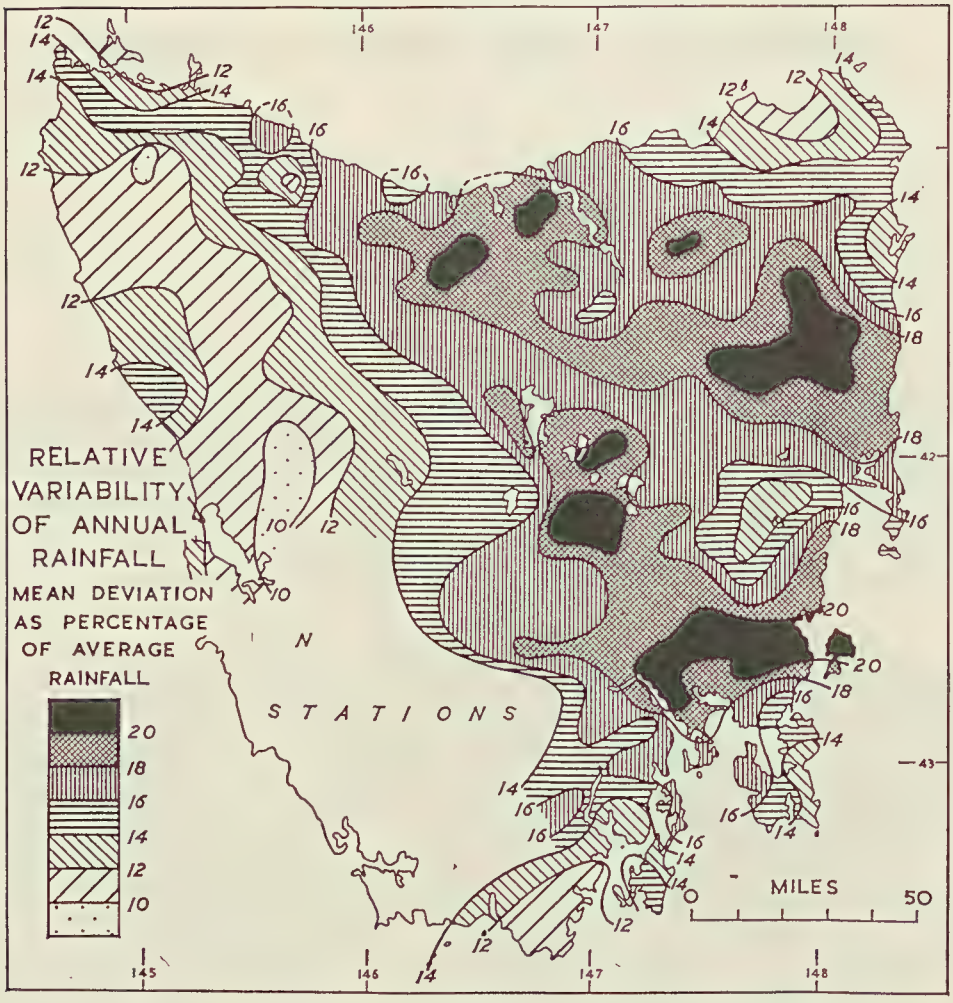

FIG. 1

The Method

The measure used in this study has been average relative variability, defined as the mean deviation expressed as a percentage of the average annual rainfall. This measure is not only simple to calculate and readily comprehensible but owing to its wide application elsewhere it also permits within defined limits comparison between Tasmania and its homoclimes. Conrad (1941) has demonstrated that where the annual rainfall is less than 28 inches—and certainly where it falls below 20 inches—comparisons of average relative variability may be inaccurate and misleading, but he suggests as a solution the representation of anomalies. Conrad established by reference to 360 stations scattered over the world that the relationship between relative variability and annual rainfall approximates to a hyperbolic curve, so that by plotting the actual average relative variabilities

and average rainfalls against the standard curve, anomalies, no longer influenced by the amount, can be calculated. Accordingly, although areas having less than 20 inches cover only small tracts of Tasmania, a map showing isanomals of relative variability of annual rainfall has been constructed. Leeper (1949) has followed the same procedure for Australia but represents Tasmania as having wholly negative anomalies without specifying values. This merely bears out the representation of Tasmania in Conrad's world map of isanomals. It would seem that neither Leeper nor Conrad has evaluated the anomaly of any Tasmanian station. Leeper's map has been re-produced by Wadham and Wood (1950).

The Data

Average relative variability has been calculated for the period from 1910 to 1934 from published yearly rainfall tables (1936). Comparatively few continuous records are available for the years preceding 1910, particularly of the Midlands, the Derwent Valley, the Central Plateau, and the west coast, so that a longer series derived from published data would have produced a less representative distribution of markedly fewer stations. For this reason Hodge (1936) has also used the period 1910-1934 in his study of the variations in annual rainfall for Tasmania and seven divisions of the State. Loewe (1948) has employed a wellnigh comparable 25-year period, 1913-1937, in his evaluation of average and extreme variability indices. It is perhaps noteworthy that for rainfall normals a minimum sample of 25 items is suggested by Conrad and Pollak (1950) as well as by Landsberg and Jacobs (1951). Accordingly, in figure 1 equivariables have been plotted primarily by reference to 71 stations with complete 25-year records, though the mean deviations for 48 stations with shorter records (20 to 24 years) were also plotted to facilitate interpolation and for a further 41 stations as occasional guides. The location of all rainfall stations in Tasmania, including the 160 used in this study, is shown on a map accompanying the yearly rainfall tables. Table 1 gives computed data for 119 stations with records for 20 to 25 years.

Relative Variability

The mean deviation expressed as a percentage of the average rainfall for the period reveals a spatial distribution strikingly different from that of average rainfall (Fig. 1; cf. map of average annual rainfall accompanying the yearly rainfall tables). At the same time, there is a remarkably close correspondence between both the 12 and 16 per cent equivariables of mean deviation and Barkley's respective 15 and 20 per cent equivariables of standard deviation, though this relationship fails to hold for the mean deviation of 20 per cent and the standard deviation of 25 per cent. Whereas in Barkley's map the east-central Midlands have percentages greater than 25 and therefore the highest variability, this region, at least from Oatlands to Swansea, is characterised by comparatively low percentages of mean deviation. Moreover, although in general the familiar principle that the lower the rainfall the greater the variability applies to much of Tasmania, the highest percentages of mean deviation for the standard period occur in the Sheffield area with an average rainfall of 48 inches. Other areas of high variability include the west Tamar, the Fingal valley, and a crescent-shaped area in the

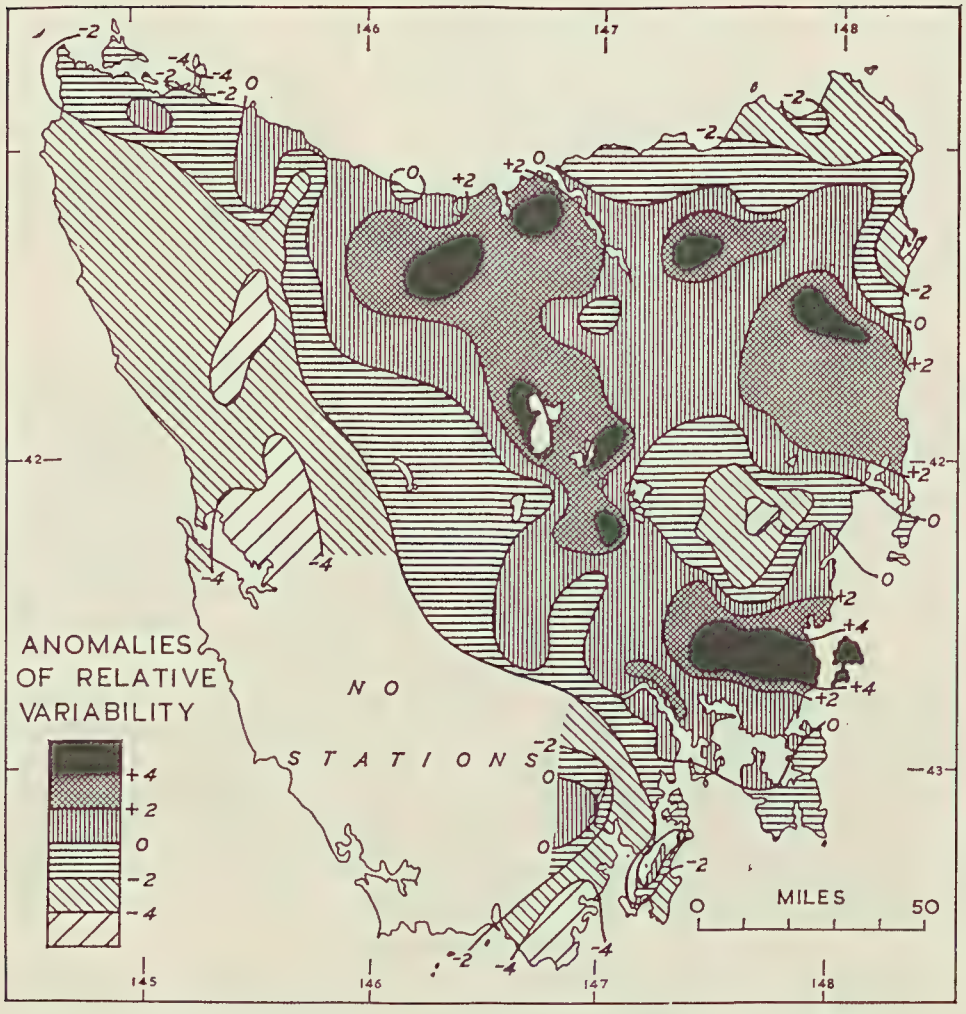

FIG. 2

south-east from Lindisfarne and Cambridge through Campania and Buckland to Orford. To these may be added St. Patrick's River and some eastern areas of the Central Plateau, though here the records are for slightly shorter periods. At the other extreme, the lowest variabilities are virtually confined to the west-coast mining region, where deviations average a little less than 10 per cent.

The general pattern of rainfall variability in Tasmania is attributable to the relative frequency and passage of the main types of depressions and the direction of the accompanying winds in relation to relief. In western Tasmania, where the rainfall is derived mainly from westerly depressions and secondaries, variability is low. But in the east, various other types of depressions bring a substantially higher proportion of the rain: they include not only Southern Ocean depressions intensifying off

the east coast and secondaries developing to the south-east, but also depressions developing in or near Bass Strait or to the east of Tasmania and even depressions of tropical origin. The greater irregularity of these depressions is reflected in the greater variability of rainfall in the east, though the detail of the variability pattern stems largely from the relief. Thus the effect of the occasionally heavy rainfall associated with easterly and south-easterly winds is evidenced by the high variability of the rain-shadow areas of the Buckland basin and the Fingal valley, as well as by the lower variability of the more elevated areas south of Lake Leake. Similarly, both the Sheffield area and the St. Patricks River valley are sheltered not only from the north-westerlies and northerlies, which bring most of the rain to these districts, but also from occasional southerlies and south-easterlies. Finally, the upper reaches of the Ouse and Lake rivers are also local rain-shadow areas, but these are located near the centre of the island and therefore derive their moisture from general rain patterns rather than from stream weather.

The irregularity of south-easterly, rain-bearing winds also accounts for south-eastern Tasmania experiencing the greatest extremes in the standard period. Thus, in the lowest-rainfall year of 1914, Rokeby failed to reach half its average—the only station and the only occasion with a rainfall more than 50 per cent below normal. At the other extreme is the highest-rainfall year of 1916, when Bagdad returned a total amounting to 193 per cent of normal, the greatest excess rainfall recorded in the period. In the same year, many other stations in the south-east, on the Central Plateau, in the Midlands, and on the east coast recorded totals exceeding 150 per cent of normal, notably Richmond with 192 per cent.

An attempt has been made at evaluating the relative variability for Tasmania as a whole by two methods. Hodge (1936) has calculated the yearly rainfall means for seven divisions of the State from the records of "77 representative stations", and then determined the yearly means for the entire State by weighting the divisional means relative to area. His yearly means for Tasmania permit an evaluation of relative variability, though the resultant percentage of 12·7 is, not surprisingly, too low, since district and more especially State averages tend to smooth out local deviations. The second approach involved the measurement of areas between equivariables in figure 1, and by weighting variabilities relative to area, the average relative variability for that portion of Tasmania served by stations was found to be 15·9 per cent. This, however, is too high because it excludes the south-west. If a tentative allowance be made for that region, the average relative variability falls to 15·4.

Anomalies of Variability

In general pattern, the isanomal map showing the extent to which Tasmanian stations depart from the world mean of variability for all places with the same average rainfall confirms the map of relative variability (Fig. 2). Yet it contrasts sharply with the uniform definition of negative anomaly advanced by Conrad and Leeper. Much of the agricultural land in Tasmania experiences a variability greater than the standard world value. Even Scottsdale and Lilydale, though located

near the zero-isanomal, have positive anomalies. In fact, only the far north-west, the far north-east, the central Midlands, and parts of the south-east, exhibit a variability below the world mean. In sum, areas with positive anomalies make up 58 per cent of that portion of Tasmania served by stations or, if negative anomalies be abscribed to the south-west, perhaps 48 per cent of the entire island. However, it should be noted that, aside from Sheffield with its outstanding positive anomaly of 7·3 per cent, the extent of the departure is nowhere very great.

Comparison with Homoclimes

Detailed isanomal maps of regions with Tasmanian homoclimes are not available, but some general comparisons may be made by reference to relative variability. Whereas for most of Tasmania the percentage variability lies between 10 and 22, Glasspoole (1921) has shown that for the British Isles the limits are 6 and 17 and for Ireland alone 6 and 12; the averages for Tasmania, the British Isles and Ireland, calculated by weighting variabilities relative to area, are 15·4, 11 and 9·5 respectively. Seelye (1940) gives the general range for New Zealand as between 10 and 20, but for the south island alone the range is from 8 to 17 and the average—calculated as for Ireland merely from the small-scale published map—12·6. For British Columbia Taylor (1947) gives percentages ranging from 9 to 16 but uses few stations, while Longley (1953) in a detailed application of the coefficient of variation gives a substantially greater range (approximately the equivalent of 10·5 to 27). But any assessment of average variability for so complex a region would seem to require far more stations than even Longley employs, and moreover involves the subjective delimitation of marine west-coast conditions. Since British Columbia is not in any case a very close homoclime, suffice it that the region appears to have a greater range of variability than Tasmania but a comparable average.

One may therefore conclude that the settled areas of Tasmania exhibit a greater variability of annual rainfall than the average for regions with similar average rainfall, and a greater variability than some, if not most, other regions with a similar type of climate.

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TABLE I.—Average rainfall, mean deviations of annual rainfall, and anomalies of variability for Tasmanian stations with records for 20 to 25 years, 1910-1934.

Station	Number of years	Average rainfall	Mean deviation	Anomaly
		ins.	%	%
Adventure Bay	24	41·7	12·2	—3·5
Andover	25	23·0	16·5	—1·0
Apsley	20	21·7	18·6	+0·7
Avoca	20	21·5	20·6	+2·6
Bagdad	25	24·4	18·6	+1·3
Beaconsfield	25	29·5	20·6	+4·1
Bellerive	25	22·8	19·1	+1·4
Black River	20	35·2	15·0	—1·1
Boobyalla	20	23·1	18·5	+0·7
Bothwell	25	21·6	17·6	—0·3
Bow Hill	21	25·7	18·8	+1·8
Bradshaw's Creek	25	38·7	15·1	—0·7
Branxholm	24	46·6	14·5	—1·0
Bridport	22	29·9	15·4	—1·1
Broadmarsh	25	22·4	19·5	+1·7
Bronte	24	39·7	15·3	—0·5
Buckland	25	26·0	22·2	+5·3
Burnie	25	39·6	17·0	+1·1
Cambridge	25	20·5	20·1	+1·7
Campbell Town	25	22·2	16·7	—1·1

Station	Number of years	Average rainfall	Mean deviation	Anomaly
		ins.	%	%
Cape Bruni	25	33·3	13·4	—2·8
Cape Grim	25	36·3	14·5	—1·4
Cape Sorell	25	47·4	13·3	—2·1
Carrick	25	27·9	15·9	—0·8
Castra	25	49·3	18·9	+3·5
Caveside	25	40·8	17·8	+2·0
Chain of Lagoons	22	31·7	18·7	+2·4
Cleveland	23	31·8	16·7	+0·4
Cluny	21	22·3	20·6	+2·8
Colebrook	23	24·1	19·5	+2·2
Compton	21	21·5	21·1	+3·1
Cressy	25	25·7	18·4	+1·5
Cullenswood	25	34·6	20·2	+4·1
Currie	25	33·9	13·3	—2·8
Deloraine	23	38·0	19·5	+3·6
Devonport	25	34·7	16·9	+0·8
Eddystone Point	25	30·1	14·3	—2·2
Ellendale	25	35·9	18·9	+2·9
Evandale	25	25·3	19·4	+1·5
Fingal	24	25·9	20·8	+2·4
Frankford	25	42·1	18·1	+2·4
Franklin	24	36·3	15·9	0
Frome Dam	25	44·6	15·5	—0·5
Glenora	25	22·0	16·9	—0·9
Glenorchy	25	26·6	18·5	+1·7
Gould's Country	25	47·8	16·1	+0·7
Gravelly Beach	24	33·7	18·9	+2·8
Hamilton	25	20·8	16·5	—1·9
Hermitage	20	22·2	21·6	+3·8
Hobart	25	26·0	17·3	+0·4
Hythe	25	37·9	10·5	—5·4
Irishtown	25	48·4	15·9	+0·5
Kellevie	23	33·0	17·7	+1·5
Lake Leake	25	31·8	16·4	+0·1
Lake Margaret	22	145·0	9·3	—4·5
Launceston	25	28·7	16·7	+0·1
Lefroy	21	33·0	17·4	+1·3
Lilydale	25	38·9	16·7	—1·1
Lindisfarne	24	19·9	21·6	+2·9
Lisdillon	22	22·8	18·4	+0·7
Lottah	24	69·6	16·5	+1·6
Low Head	25	27·9	16·6	—0·1
Lunnawanna	23	33·0	16·3	+0·1
Maatsuyker Island	25	45·9	14·0	—1·5
Magnet	24	87·3	11·2	—3·4
Marrawah	22	46·6	13·1	—2·4
Mathinna	25	34·5	21·5	+5·4
Miena	22	33·5	22·0	+5·8
Moina	24	70·9	17·9	+3·1
Moorleah	20	47·8	16·6	+1·2
Mount Lyell	25	117·2	9·9	—4·1
Mount Nelson	25	25·8	17·8	+0·9
Mount Seymour	25	24·7	19·8	+2·6
New Norfolk	25	22·0	16·9	—0·9
Northdown	25	31·0	19·2	+2·9
Oatlands	25	23·2	17·7	0
Ormley	25	21·4	20·4	+2·4
Osterley	22	28·8	17·2	+0·6
Port Arthur	25	40·3	14·5	—1·3
Premaydena	24	29·5	16·6	+0·1
Queenstown	25	99·1	10·4	—3·9
Regatta Point	25	65·8	10·8	—4·1

Station	Number of years	Average rainfall	Mean deviation	Anomaly
		ins.	%	%
Renison Bell	23	88·9	10·5	—4·1
Richmond	25	20·7	19·7	+1·4
Ringarooma	25	49·2	17·6	+2·2
Robeville	21	26·5	16·5	+0·3
Rokeby	25	19·7	19·5	+0·8
Rosebery	22	80·8	11·5	—3·2
Ross	25	19·4	16·8	—1·9
Sandford	25	21·9	18·1	+0·3
St. Helens	25	32·0	12·5	—3·8
St. Patrick's River	23	55·9	20·6	+5·4
Scamander	23	26·9	14·9	—1·9
Scottsdale	25	42·6	16·2	+0·5
Sheffield	25	48·7	22·7	+7·3
Sorell	25	21·8	19·3	+1·5
Spreyton	20	37·3	17·2	+1·3
Lovely Banks, Spring Hill	25	20·0	19·5	+0·7
The Springs, Mt. Wellington	25	55·7	14·8	—0·4
Stanley	25	36·9	11·4	—4·5
Steppes	23	28·3	19·4	+2·7
Strahan	22	65·1	11·9	—3·0
Swan Island	25	24·5	14·5	—2·7
Swansea	25	23·4	15·7	—1·9
Tower Hill	25	35·6	19·5	+3·5
Triabunna	25	27·0	19·9	+3·1
Tyenna	23	43·0	12·7	—2·9
Ulverstone	23	37·9	15·7	—0·2
Uxbridge	25	32·2	14·0	—2·2
View Point	21	24·7	17·4	+0·2
Waratah	25	87·0	10·3	—4·2
Westbury	25	33·4	16·5	+0·4
Wihareja	22	31·4	19·0	+2·7
Wilmot	24	49·2	16·6	+1·2
Woodbury	23	18·5	18·1	—0·8
Wood's Quoin	23	29·0	20·8	+4·2
Wynyard	25	40·6	15·8	0
Yolla	25	57·9	12·0	—3·1
Zeehan	25	95·5	11·9	—2·5

THE INDO-PACIFIC REDBROWN LOGGERHEAD TURTLE, *Caretta caretta gigas* DERANIYAGALA, AND THE LEATHERY TURTLE, *Dermochelys coriacea* (LINNE) IN TASMANIAN WATERS

By

E. O. G. Scott and B. C. Mollison

(With 1 Plate)

Abstract

In their *Synopsis of the Vertebrate Animals of Tasmania*, 1924, Lord & Scott notice a leathery turtle, *Dermochelys coriacea* (Linné, 1876) obtained in 1889: this appears to be the only formal account of any chelonian from our waters. Twelve additional records are now given. One of these is a second example of the luth, from the same locality as the 1889 individual. Of the eleven others, three are based on actual material, and are determined as the Indo-Pacific redbrown loggerhead, *Caretta caretta gigas* Deraniyagala, 1933; the remainder, based on hearsay, being thought to be attributable also to this species. Localities from which reports or specimens were received range from Stanley, round the West Coast (chief source), to Bruny Island.

Apart from a single individual of the leathery turtle or luth, *Dermochelys coriacea* (Linné, 1766)—a sporadic, almost cosmopolitan form, apparently common nowhere, but liable to be encountered upon occasion almost anywhere outside the arctic and antarctic regions—that came ashore on the south-east coast in the latter part of last century, no chelonian has hitherto been known from our waters. There are here presented records of the appearance within the last five years of no fewer than ten turtles, of which three are known to be, and the remainder probably are, the Indo-Pacific redbrown loggerhead, *Caretta caretta gigas* Deraniyagala, 1933: a second occurrence of the luth about 1945 is also noted.

The finding of the loggerhead in Tasmania represents something more than merely another entry in this State's faunal list, interesting though the addition of such a large and well-known animal certainly is. In the light of recent developments in the systematics of marine turtles in general and of contemporary investigations into speciation and raciation in loggerheads, particularly in respect of range as a function of thermophily, and the correlations of variations, secular and periodic, of ocean currents and temperatures with chelonian colonization or penetration, the present material becomes a source of some significant morphological

and distributional data. A study made on the Tasmanian loggerheads and of their bearing on some of these problems that has grown to exceed the dimensions appropriate to presentation here will, it is hoped, appear later: the present notice is, in these circumstances, confined to a formal record of occurrence, accompanied by an enumeration of the material in hand.

It may perhaps, however, usefully be observed in passing that for over a century it was not generally realized that there are at least two well-differentiated species of loggerheads, the confusion largely being traceable to an overlap in distribution over the greater part of the combined range of the two main forms. More conservative opinion now recognizes two species, each with two subspecies, as set out below: by some herpetologists each of these four forms is accorded specific status, the second form in the subjoined list, further, being referred by some to a third genus, *Colpochelys* Garman, 1880.

Lepidochelys olivacea olivacea (Eschscholtz, 1829). Range: Indo-Pacific (probably the whole of the Pacific), West Coast of Africa.

Lepidochelys olivacea kempi (Garman, 1880). Range: essentially a native of the West Atlantic; occasionally reaching Great Britain.

Caretta caretta caretta (Linné, 1766). Range: Atlantic, Mediterranean.

Caretta caretta gigas Deraniyagala, 1933. Range: Indo-Pacific (probably to Pacific generally; possibly travelling up round West African coast to Mediterranean).

Family Dermochelyidae

Genus *Dermochelys* Blainville, 1816

Testudo coriacea Linné, 1766, Syst. Nat., ed. xii: 330.

Dermochelys coriacea (Linné). Boulenger, 1899, Cat. Chelon. Brit. Mus.: 80. de Rooij, 1915, Rept. Indo-Aust. Arch., i: 313.

Record.—The only Tasmanian specimen of which we have found published record came ashore at Fortescue Bay, south-east coast, in March, 1889 (Lord & Scott, 1924). This animal is now mounted in the Tasmanian Museum, Hobart (Reg. No. 13444/C34). While not attaining the dimensions—a length of 9 ft. and a weight of more than a ton—ascribed by some authors to this species, it is quite a large example, exceeding in total length and length of carapace the maximum noted by Gadow (1909) for the British national collection. Total length 6 ft. 10 in., median length of carapace 4 ft. 11 in., maximum width of carapace 3 ft. 0 in.; all measurements between parallels.

In the course of our inquiries regarding loggerheads, we received from Mr. Jack Fazackerly a report of a turtle he saw leave the water and come ashore at Fortescue Bay about 1945. It was described as being 7-8 ft. in length, and as having the body leathery, and partly covered with seaweed. There seems little doubt this animal was a luth. It is curious our only two records should come from the same locality.

For Victorian records see McCoy (1885; dec. xi: 1, pl. 101), Kershaw (1911), Lucas & Le Souëf (1909: 194). A recent occurrence noted in the Melbourne press was that of a 650-lb. turtle caught off Cape Schanck by Mr. C. Mannix on 17th February, 1955: Professor O. W. Tiegs has kindly informed us that this animal, parts of which are preserved in the Zoology Department, University of Melbourne, is a luth. For records in New South Wales see Lucas (1914): in South Australia, Waite (1929): in Western Australia, Glauert (1928), Campbell (1947). See also MacInnes (1951).

Family CHELONIIDAE

Genus *Caretta* Rafinesque, 1814

Caretta caretta gigas Deraniyagala, 1933

[*Part.*] *Testudo caretta* Linné, 1776. Syst. Nat., ed. XII: 351.
[*Part.*] *Thalassochelys caretta* (Linné). Boulenger, 1889, Cat. Chelon. Brit. Mus.: 184.
[*Part.*] *Caretta caretta* (Linné). de Rooij, 1915, Rept. Indo-Aust. Arch., I: 310, figs. 117, 118 (omitting extra-Indopacific records).
Caretta gigas Deraniyagala, Spol. Zeyl., XVII, 1: 66, figs. 4-6.
Caretta caretta gigas Deraniyagala. Deraniyagala, 1946, Spol. Zeyl., 24, 2: 97, figs. 1, 2: 1946, Spol. Zeyl., 24, 3: 196, pl. XXV.

A. Records Based on Specimens Examined

ANIMAL E_1

Record.—At about 9 a.m. on 24th November, 1951, about half a mile north of Mount Cameron West, at midtide level (the tide then making), on a sandy one-mile beach, facing west to the open sea, one of us (B.M.) found a turtle, fresh-smelling, and recently blown by flies. The plates of both carapace and plastron were heavily overgrown with green weed, and encrusted with barnacles and lime concretions: sutures, especially those of the marginals, were indistinct. The head, with atlas and axis attached, was severed, and was later carried to Woolnorth. With the assistance of another member of the party, Mr. Bruce Ellis, the decapitated animal, of an estimated weight of about 160 lb. was dragged up above highwater mark: unfortunately, we have not hitherto succeeded in retrieving these remains.

Material.—(*a*) *Cranium.*—Length: condylobasal 144; to level of posterior border of squamosal 180; to tip of supraoccipital spine 192·5. Maximum width 140. (*b*) *Mandible.*—Length 129, width 110. (All measurements between parallels.) Cranium retains some scutes and mandible carries horny beak.

ANIMAL E_2

Record.—Mr. Max Hardy, Stanley, informs us that in March, 1951, he saw the remains of a turtle measuring about three feet by two feet at the residence of Mr. Bailey, at the Arthur River ferry. Mr. J. Breheny, M.H.A., dates this find as December, 1951. Some remains were later obtained from Mr. Bailey, who had collected the animal near his home, by Mr. A. M. Olsen, C.S.I.R.O., who has very kindly placed them at our disposal for description.

Material.—(*a*) *Carapace.*—This is broken into six main pieces, but sufficient of it remains to allow of a general reconstruction of its outline: half a dozen largish and several smaller sheets of paper-thin brown flexible horny investment remain, covering in all about one-sixth of the total area. Length: between parallels, as carapace rests on table 763; median, direct 804; median, following curves, estimated 838. Maximum width, direct 560. (*b*) *Cranium.*—Length: condylobasal 175; to level of posterior border of squamosal 223; to tip of (much damaged) supraoccipital spine 180. Maximum width 164. (*c*) *Mandible.*—Length 154; width 135.

ANIMAL E_3

Record.—On 24th August, 1955, the Tasmanian Museum, Hobart, received a complete animal (Reg. No. 13445/C35) from Adventure Bay, Bruny Island. Apart from a transverse slit in the integument near the base of the neck and a little distal abrasion of the forelimbs, the specimen, which is at present preserved entire in formalin, is in excellent condition. It is thought to have been lying for several days on the beach before it was collected. Total length (snout-tip to tail-tip) 537·5. Carapace: median length 378·5; maximum width 350.

B. Records Based on Reports Only

ANIMALS R_1-R_4

On a mention of Animal E_1 being made, on the day of its discovery, to Mr. G. Wainwright, the Van Diemen's Land Company's manager at Woolnorth, he stated he had seen, within the preceding two months, four stranded turtles at Studland Bay (about 12 miles north of the point at which E_1 was found).

ANIMAL R_5

Summary of data supplied, as answers to a questionnaire, by Mr. Clyde Clayton, Port Davey. One turtle, dead about two weeks, observed, at normal hightide mark, in fine weather, at Stephens Beach, Port Davey, February-March, 1949. No weed or other growth; carapace thought to be leathery; no estimate of weight; length about three feet; thought by visitor from Queensland to be a green turtle; uncertain whether beak snub or hooked; no data on number of claws; remains unlikely to be available; no sketches; no knowledge of other strandings.

ANIMAL R_6

Summary of data supplied, as answers to a questionnaire, by Mr. Max Hardy, Stanley. One live turtle seen, in very fine weather, swimming about six miles north-east of the Nut (Stanley), March, 1951. No weed or other growth noticed; carapace a hard shell; no estimate of weight, length placed at eight feet by six feet; snub beak; no information on claws; no sketches; fairly light colour below; animal observed on same occasion by Mr. George French and Mr. Tom. Frebourgh. Question, 'Any other records? Names of people who have seen specimens?': answer, 'I think you can safely say every fisherman in Stanley'. No remains known to be available near Stanley; but reference made to Animal E_2.

ANIMAL R_7

We are informed that a second specimen (see Animal E_2) was found by Mr. Bailey near the Arthur River: date unknown.

On the evidence available, it seems probable Animals R_1-R_7 were loggerheads.

For South Australian records see Waite (1929): Western Australian occurrence noted by Glauert (1928), Campbell (1947).

NOTE.—Since this paper was drafted, we have learnt that a turtle was found at Currie, King Island (Tas.), in 1951, by Mr. Ray Clarke. This record has not been incorporated in the text, but it is taken into account in arriving at the number of new records (12) noted in the Abstract.

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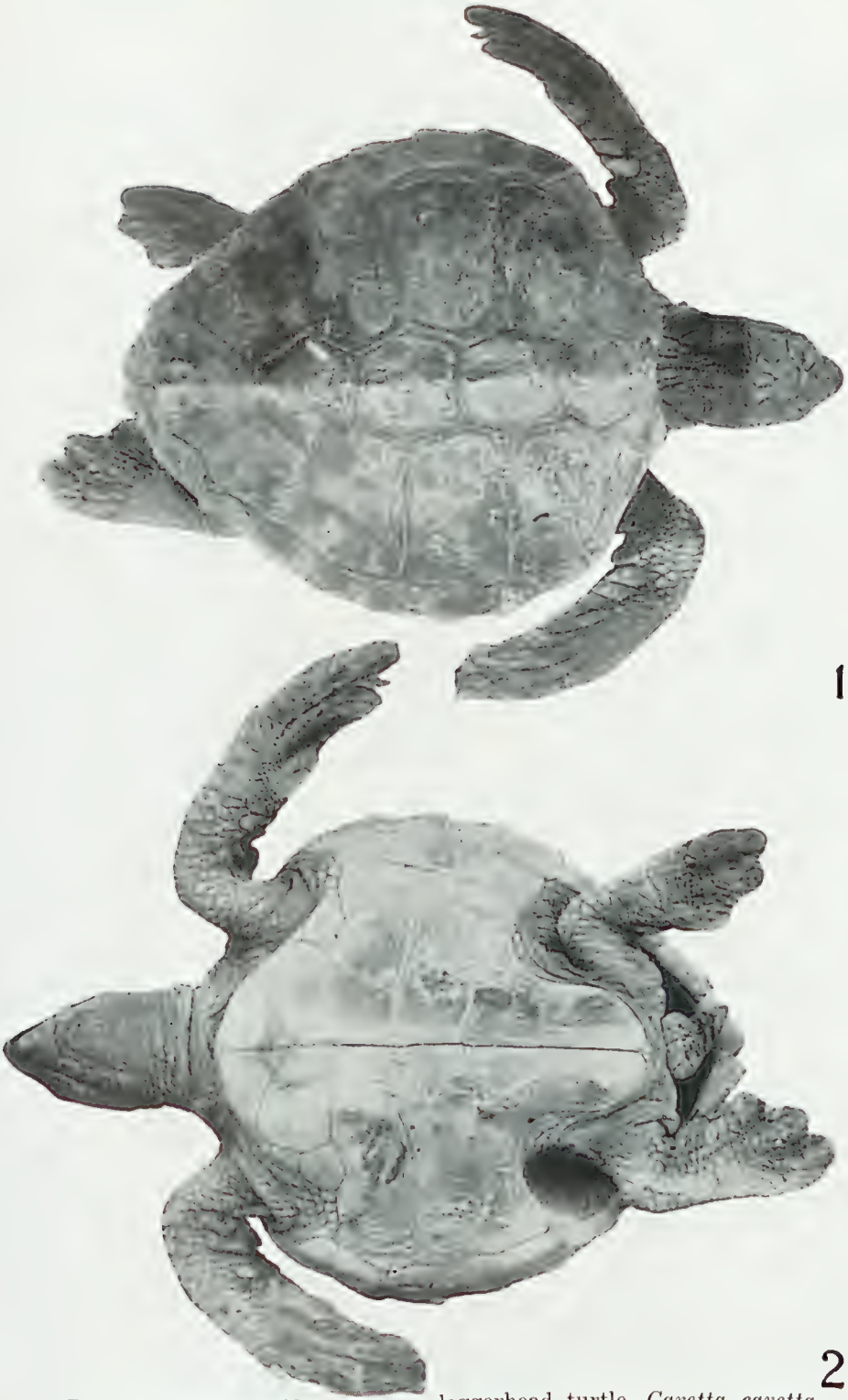

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Plate 1.—Indo-Pacific redbrown loggerhead turtle, *Caretta caretta gigas* Deraniyagala, 1933. A Tasmanian specimen from Adventure Bay, Bruny Island; 24th August, 1955: Tasmanian Museum, Hobart, registered number 13445/C35. Total length (tip of snout to tip of tail) 537·5 mm.

Fig. 1.—Dorsal aspect.

Fig. 2.—Ventral aspect. [*William Jackson photo.*]

THE GEOLOGY OF THE WEST COAST RANGE OF TASMANIA

Part II

Structure and Ore Deposits

By

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(With 13 Figures and 2 Plates)

(*Communicated by Professor S. Warren Carey*)

VI. Structure.

Four major periods of earth movement have been recognised in Tasmania; these have been set out by Carey (1953) as Upper Cambrian, post-Lower Devonian and pre-Middle Carboniferous, Jurassic(?), and early Tertiary. The first two of these, the Tyennan and Tabberabberan orogenies, were characterised by compression and folding of geosynclinal sediments, and the last two by block faulting and epeirogenic movements of the crystalline massif of Tasmania. The post-Permian structures (which will be treated briefly) are of interest here only insofar as they may complicate the picture of the Palaeozoic orogenies.

Post-Permian Faults.

The presence of "post-dolerite" faulting in the West Coast area has been deduced by several workers, and the basis for their deductions has been set out by Edwards (1940). One of these faults is that which runs N.N.W. from Mt. Sorell past the Sisters Hills towards Dundas (see Strahan, Queen River and Yolande map sheets); Carey (1953, p. 1123) shows this fault in a general map of the region, and in the Zeehan area has called it the Long Fault. Although it follows the strike of Devonian faults or flexures the fault is anomalous in that it has a westerly downthrow and cuts some Devonian structures. On the other hand, it readily fits into the pattern of the Tertiary faulting which produced the Macquarie Harbour depression (see map by Fairbridge, 1949, p. 150), and as it follows the boundary between the Range and the Howards Peneplain it can be interpreted as having down-faulted an old land surface.

More or less aligned with the fault in the Queenstown area is a Devonian flexure which separates two pieces of country of different structural pattern and which in depth must be a major Devonian fault;

it may be that the younger fault represents a revival of movement of the older structure but with a reversed direction. In any case, it is very difficult to interpret either of the coinciding structures, and all that need be said is that the later fault which cuts out the Gordon Limestone at the King River must have a throw of at least 1,000 ft., and is probably Tertiary in age.

In view of the widespread Jurassic and Tertiary faulting of Tasmania it is possible that other north-westerly faults cut the region, but so far as the West Coast Range is concerned this is improbable. Any faults which might cut the area would dislocate the old Carboniferous peneplain and upset the general concordance of summits in the range. It is possible that faults with throws up to 300 ft. might pass undetected but such small faults would not materially affect the much coarser Devonian structures.

Cambro-Devonian Structures.

The Dundas Geanticline.

It was shown in Part I of this work (Bradley, 1954) that the Dundas Trough of sedimentation deepened sharply to the west of the Tyennan Block and that at least 10,000 ft. of sediments were laid down before the end of the Upper Cambrian. Then the Tyennan Orogeny raised the Dundas Ridge and created the Jukes Trough between the ridge and the block (fig. 4).*

The trough was a sharply angular depression shelving to the east and bounded on its western and deeper side, throughout the period of deposition of the Dora Conglomerate, by what was probably an active fault; it may be considered as having been similar to the present-day "fault angle depressions" of New Zealand. For our immediate purpose the depression can be regarded as an asymmetric syncline and the Dundas Ridge can be interpreted as an asymmetric anticline thrust against this syncline. It has been shown that the Dundas Ridge was probably emergent during the deposition of the Dora Conglomerate. It was also shown that the Jukes Trough must have been subsiding continually during the Tremadocian and that in a relative sense the Dundas Ridge was rising. It will be shown that the position of the main anticlinal uplift of the Devonian orogeny coincided with that of the Cambrian movements and it follows that the Dundas Ridge was merely one aspect, the late Cambrian geomorphic aspect, of an evolving and long enduring anticlinal structure. In this wider aspect the structure will be called the Dundas Geanticline; following Carey's (1953) usage the structure resulting from the late Cambrian orogeny will be called the Porphyroid Anticlinorium and that resulting from the Devonian orogeny will be called the West Coast Range Anticlinorium.

After the major uplift of the geanticline in late Cambrian times it is probable that the Porphyroid Anticlinorium was bent round the north-west corner of the Tyennan Block, being widest near Mt. Bischoff, and that it plunged and died out to the south near Macquarie Harbour.

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* Figures 1-4 are to be found in Part I of this work.

There, sedimentation was probably continuous from Middle Cambrian to Silurian times, but to the north and east the land was only submerged after Tremadocian times. During the Devonian orogeny there was renewed movement of the geanticline, and the sediments of the Jukes Trough were compressed along with the Porphyroid Anticlinorium and the covering Gordon Limestone and Eldon Group sandstones; the resulting complex structure forms the West Coast Range Anticlinorium, and the last structural relic of the Jukes Trough forms the King-Sophia Synclinorium. The West Coast Range Anticlinorium (plate I) is made up of a number of echeloned smaller folds and these consist of yet smaller folds so that if the anticlinorium is described as a first order fold the others are conveniently termed second and third order folds.

Because of the asymmetry of the geanticline and the 5,000 ft. of sediments which were deposited between the orogenies the Porphyroid and West Coast Range Anticlinoria are not quite coincident, and the Devonian fold axis lies perhaps half a mile to the east of the Cambrian axis. The present state of erosion is such that post-Cambrian sediments have been entirely stripped from the crest of the West Coast Range Anticlinorium and only the strata of the anticlinal limbs remain. The

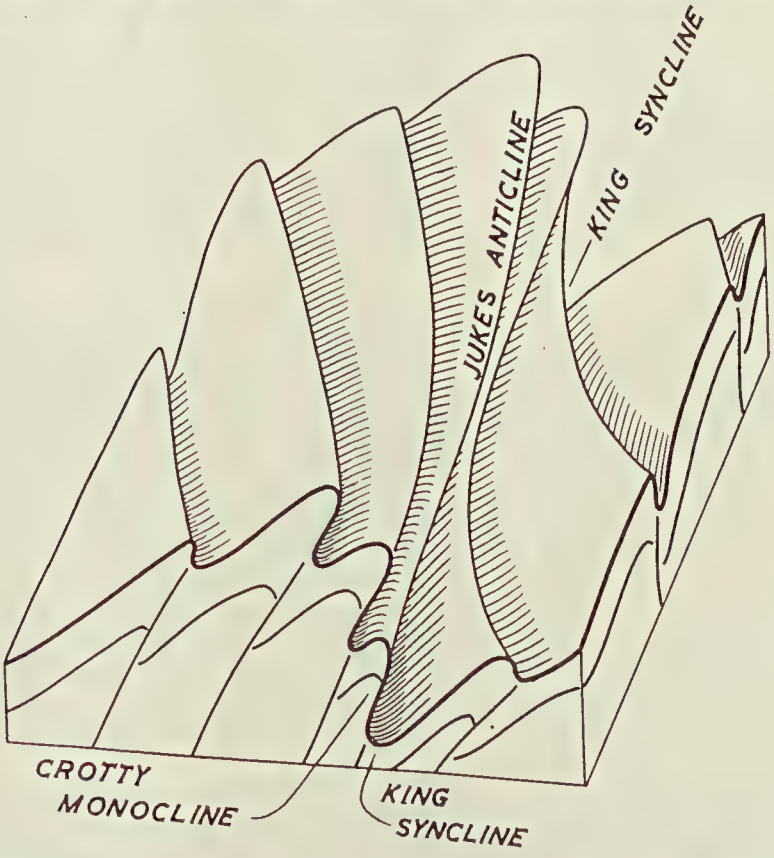

FIG. 5.—The idealised structure of the Jukes Anticline, Crotty Monocline and King Syncline and their relations to the northwest folds.

eastern and steeper limb built of the thick Owen and Dora Conglomerates is the more prominent, and this forms the bulk of the West Coast Range.

What follows is a detailed study of the structure of this limb of the West Coast Range Anticlinorium together with a broad study of the anticlinorium and synclinorium as a whole.

Second Order Folds.

Although it is convenient to speak of the vertical limb in the singular as the " Main Monocline " it is a compound structure like the anticlinorium, and just as that first order fold is made up of second and third order folds, so the monocline is made up of echelonned second and third order monoclines. Reading from south to north on plate I the second order folds are the Sorell, Jukes, Thureau, Read, Tyndall and Farrell; and the best defined of the monoclines, thrusts or overfolds are the Sorell Overfold, Crotty Monocline, Tyndall Fault, and Farrell Monocline. The second order structures are simplest, and best typified by the Jukes Anticline and the Crotty Monocline (fig. 5).

The Jukes Fold is asymmetric, and its eastern limb, which is vertical or slightly overturned, results from the upturning of the thickest conglomerates of the Jukes Trough. Consequently the vertical part of the limb of Owen Conglomerate is wide and the top of the formation does not quite coincide with the westward margin of the Tremadocian subsidence but lies some five furlongs to the east. The faulted margin should, theoretically, be marked by the westward limit of the thick conglomerates, and is so marked within a few chains at Mt. Owen, but irregularities caused by step faulting and uneven subsidence, by overstepping of the Owen Conglomerate on to the uneven surface of the Dundas Ridge, and by metamorphism of the Owen Conglomerate, mask the line.

Because the Owen Conglomerate is silicified and is resistant to erosion, the western margin of the thickest conglomerates is more or less the western margin of the crest of the quartzite hills, and this line is also marked by the presence of a remarkable mineralised tear fault, the Lyell Shear. The shear represents, with qualification, the actual fault line of the Cambrian subsidence and the eastern margin of the Dundas Geanticline. The origin of the shear, which is a transcurrent fault, is related to the fact that when the Dundas Geanticline was rejuvenated in the Devonian it moved northwards and carried the overlying strata with it. The country on the eastern side of the fault was left behind and a transcurrent fault was formed in the strata overlying the older fault line. The vertical movement on the west side of the fault was to a slight extent localised immediately over the fault line so that the shear is locally monoclinal, but in general the vertical movement was distributed through the 5,000 ft. of overlying strata and formed the larger Main Monocline of the range.

The anticlinorium as a whole is thought to be made of several echelonned units like the Jukes Anticline which have had very similar histories and which are probably structures inherited to some extent from the Tyennan orogeny. Although it would be possible to have had a simple Jukes Trough with a continuous western wall, and for the whole to have been folded *en echelon* in the Devonian, this would not quite explain the

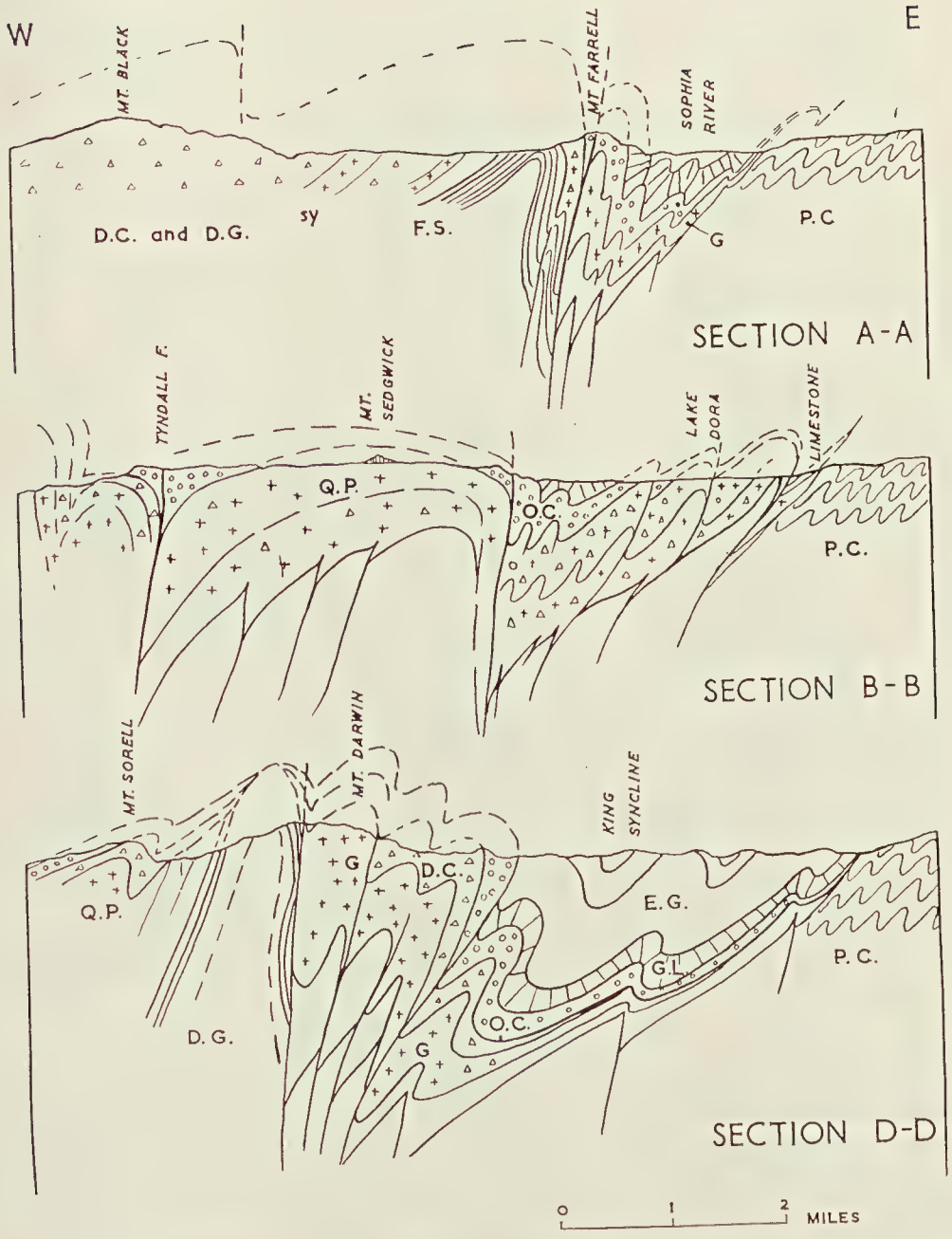

FIG. 6.—Sections across the King-Sophia Synclinorium (see Plate I). D.G.—Dundas Group; E.G.—Eldon Group; P.C.—Precambrian; O.C.—Owen Conglomerate; D.C.—Dora Conglomerate; G.L.—Gordon Limestone; G.—Granite; Q.P.—Quartz Porphyry.

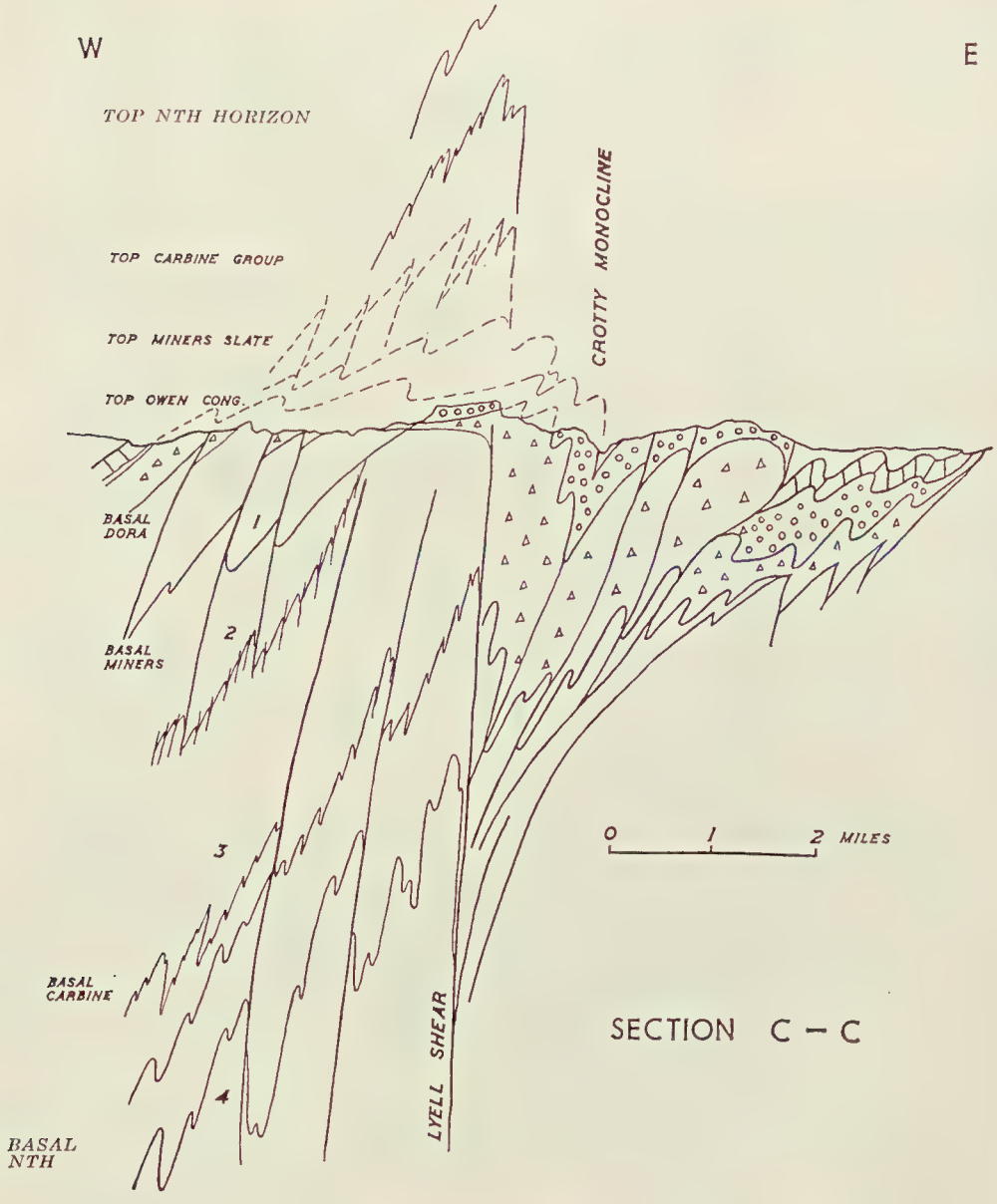

FIG. 7.—Section across Mt. Huxley (see Plate I). The section is extrapolated in depth in accord with the text, page 71 of this article, by projection of folds along plunge lines. The figures indicate zones of 1. massive shears; 2. slaty cleavages; 3. plication and schisting; 4. plastic flow. The latter should be scaled off to a depth several miles lower than the page allows.

observed pattern of outcrops. It is preferable to visualise the Porphyroid Anticlinorium as an echelonned structure and to imagine the Jukes Trough as subsiding along three echelonned faults during the Tremadocian. Then, when rejuvenation occurred, the thickest conglomerates would always form the western and steeper limb of each subsidiary basin. In this way we can explain the parallel variation in thickness of sediments seen across the folds of Mt. Sorell, Mt. Jukes and Mt. Farrell.

The comparison of structure and stratigraphy between one second order fold and another is complicated considerably by the fact that in the central section of the range, near Mt. Tyndall, the anticlinorium and synclinorium rise to a culmination, and we see a more deeply eroded section than at either Mt. Jukes or Mt. Farrell. Had the structures not been echelonned it would have been possible to take direct advantage of the culmination and to use an axial view along the plunge of the synclinorium to visualise the nature of the bottom of the King Syncline. As it is, none of the second order folds are quite comparable with another, and it is difficult to use the " axial plunge " method. It is even difficult to make simple comparisons of folds by name because the echelonned second order folds usually plunge, and the section through any one must be compared only with a carefully chosen section through any other fold.

With this caution in mind it is possible to compare both the Tyndall Fault and the Dora Shear with the Crotty Monocline in depth, and, in a general way, to project a series of sections at different depths across the King-Sophia Synclinorium. In the region of culmination the deep synclines of the Sophia and King Rivers are represented by the elevated Tyndall Range, which, although 1,200 ft. above those synclines and, despite its being a broad anticline, is a structural low between the Sticht Range (Tyennan Block) and Mt. Read (the anticlinorium). Thus, the sediments, general structure and metamorphism of the east-west section in this area must be somewhat similar to that in depth in the King Syncline at Crotty. A comparison of the Tyndall Fault and the Crotty Monocline (figs. 6B and 7) shows that, whereas the Crotty Monocline rears and thrusts vertical Owen Conglomerate against Eldon strata of the King Syncline, the Tyndall Fault thrusts vertically bedded quartz porphyries (Dora Conglomerate) against the westerly dipping Owen Conglomerate of the low Tyndall Anticline; in both cases a sharp fault angle is formed.

Third Order Structures.

For convenience in the account which follows, the West Coast Range Anticlinorium will often be called the anticlinorium, and the Porphyroid Anticlinorium will always be given its full title. The anticlinorium has already been divided into second order folds, and on examination of the map (plate I) it is seen that these are made up of a large number of small overfolds or thrust masses which strike in north-westerly directions; these third order folds, which are thrust towards the north-east, will be called North-West Folds. The Main Monocline is also cut by a large number of north-east trending third order fault structures which are expressed as monoclines or faults; these will be called North-East Faults. All of these structures, along with the north-south tear faults of the Lyell Shear type, are shown on the map.

On examination of the structural pattern it is immediately apparent that a transverse east-west structure, the Linda Disturbance, separates the Range into two structural units. Ignoring this for the moment, the pattern is immediately recognisable as typical of areas which have been subjected to north-east—south-east dextral shearing couples. There are very close similarities between this area and the Livermore Region of transcurrent faulting in California (Vickery, 1925), and even closer analogies between it and the highly sheared and mineralised copper belt of the Front Range of Colorado (Lovering and Goddard, 1950). In the active orogenic belt of New Zealand this pattern appears to the writer to be dominant in some late Tertiary foldings, and it is commonly associated with present-day transcurrent movement. Quite apart from these analogies, or by argument from more direct field evidence, it is possible by the inspection of the pattern to deduce that the region has suffered north-east—south-west compression and north-south shearing. The fault pattern can then be interpreted by use of the parallelogram of forces to show the lines on which this compression has been resolved and the probable directions of movement on most faults can be qualitatively assessed as follows:—

1. N.-S. faults are dextral transcurrent faults (dextral and transcurrent in the sense of Anderson, 1942, p. 54).
2. N.E.-S.W. faults are tensional.
3. N.W.-S.E. structures are compressional.
4. E.-W. faults are sinistral transcurrent faults

Because of our lack of knowledge of the orientation of the shearing stresses and of the shearing strengths of the rocks little more can be deduced, but it might be suspected by analogy with the branch faults of the Livermore Region that the north-west faults are sometimes dextral tears; this would apply particularly to those with a more northerly trend. The field occurrence of each of these structural types may be examined next.

The North-West Folds.

The North-West Folds vary in trend from N. 60° W. to N. 20° W, and they are rarely simple folds but are commonly asymmetrical or overthrust towards the north-east; despite their variation in form and trend the general terms north-west fold, thrust, or fault will be applied to these structures. They rise in the Zeehan Basin as simple folds of Eldon strata, and as they pass into the older rocks in the core of the anticlinorium they change into asymmetric folds and then into thrusts; at the same time, they swing in gentle arcs and pass into a north-south line along the crest of the Main Monocline. There, all minor folds become thrusts, but still further east they appear to pass out of the monocline into the King Syncline, and beyond that the folds pass again into north-west thrusts as they rise to the Tyennan Block.

It appears that the folds can be seen as folds only in the structural lows where they occur above the middle of the Owen Conglomerate, and that below that horizon they are steep thrusts or shears. This is clearly shown by the broken structures in the Lynch Slates which are folded a few points (e.g., north of Mt. Murchison) and by the intense

brecciation of the Cambrian lavas. Where the lavas contain slate bands the slate is sheared, comminuted and mixed with all kinds of fragments, and it is the porphyritising of this mixture which has produced many of the inclusion-crammed porphyries of the region.

Quite apart from variation with stratigraphic depth, the north-west structures become more intensely thrust along the crest of the anticlinorium and some of the thrusts, on Mt. Jukes for example, show a forwards displacement of 150 yards. The thrust planes also vary in dip, for the thrusts in the Queen River Valley are steeper than 70°, those on the western face of Mt. Owen are about 50°, and those of Mt. Jukes are as low as 40°.

The passage of the north-west thrusts into the Main Monocline is best seen on the eastern side of Mt. Jukes where the vertical or slightly overturned quartzites stand as an almost continuous ridge for several miles. This ridge is seen to be cut obliquely and to be slightly offset by vertical shear planes which trend a little west of north. Aligned, but not demonstrably related to any particular one of these shears, are the long, more or less synclinal ridges which run up the flank of Mt. Jukes and pass with a small break into thrust synclines of the mountain top. The merging of the north-west structures, which is probably more perfect than field evidence indicates, is shown in figure 5, which also illustrates how the composite Crotty Monocline passes into the King Syncline as a series of tight folds which gradually open out. A glance at the Jukes and Darwin map sheets (published with Part I) shows how this happens—how the north-west structures are repeated by the north-east faults and how these faults are compensated by the tilting of blocks. The tilting results in many apparent anomalies, such as that at 366/793, Darwin Sheet, for it obscures the simple mergence of folds and often appears to set anticlines in line with synclines. An appreciation of the tilting effects is pre-requisite to the understanding of the north-west folds as they are seen in the field, for otherwise they appear hopelessly jumbled.

The field appearance of the north-west folds is worth a special note for, considering the complexity of the structure and the difficulty of the country, the evidence for them is very clear and is fully adequate to the purpose of a structural study. The excellent geomorphic expression of structures involving Eldon strata and Gordon Limestone has already been mentioned, but there are also numerous river gorge and scarp sections in which folds and thrusts are admirably displayed. In the older strata reverse faults are marked by sharp gullies in the hogback of the Miners Slate, but it is difficult to follow faults through the breccias and porphyroids, and some uncertain interpolations of faults have had to be made there. On the other hand, the great thrusts in the quartzite cappings of the range and the distinctive red and white thrust sheets of Mt. Owen and Mt. Jukes can be seen from a distance of ten miles away in the north-west. The traces of these faults are difficult to map for the thrust surfaces and topographic surfaces coincide and both are exceedingly complex; the same difficulty applies to the mapping of the Owen Conglomerate, for erosion is usually halted at its upper surface and a direct plan of outcrops, even if contours could

be supplied, would be unintelligible on anything less than a 25-inch scale. These difficulties are partially resolved by using a smoothed surface of projection for the one-inch maps, and by showing traces and outcrops much simpler than they are in fact.

The Linda Disturbance.

As already noted and illustrated in Plate I this structure occupies an east—west zone which cuts across the range. The southern margin of the zone runs through Mt. Owen while the northern limit is marked by the east—west faults which run just south of Lake Margaret and along the North Eldon River. The axis of the structure runs east—west through Mt. Lyell and against it the north-west folds from both sides are deflected and thrust. The zone as a whole is seen as a structural low crossing the anticlinorium and lowering it by about 2,000 ft., and as a zone of intense shattering and faulting which extends for many miles to both east and west. Towards the west the faulting downthrows to the south, and against the zone the north-west folds are deflected, compressed and thrust, while the country is pneumatolised and the faults are mineralised with galena. Towards the east the Linda Disturbance follows the Nelson Valley and continues ten miles or more past Bubb's Hill, sometimes as a trough-like system of faults but at others as a stepwise system downthrowing northward. The Gordon Limestone at Bubb's Hill is mineralised with galena, and the east-west faults further east carry arsenopyrite; as the block faulting of Tasmania is not accompanied by mineralisation the structure must be pre-Permian and, in view of the fact that the structure downthrows Silurian strata, it is probably of Devonian age.

The Linda Disturbance is an important regional structure which has first order dimensions and affects the Precambrian Block and West Coast Range alike. Near Mt. Lyell the deflection of folds and their overturning suggests that the disturbance is a zone of tearing; it is far too complex to be a single tear fault, but in plan it looks as if the north-west folds have been folded normal to the horizontal plane and dragged against the axis of the disturbance.

The North Lyell Fault which closely follows the axis presents the only known direct evidence of strike slip and this has been described to the writer by Dr. C. Loftus Hills as taking the form of large horizontal channels and striations which slickenside the walls of the fault in the workings of the old North Lyell Mine. Other east-west faults, such as those on the south side of Lake Margaret, show such a contortion of the rocks to either side that the folds are visible on aerial photographs, and this degree of contortion in the absence of great throw may be attributed to tear movement.

There are two possible explanations of the Devonian structures of the Linda Disturbance; the first assumes the existence of a faulted depression across the site of the range before the Devonian orogeny, and it supposes that the north-west folds were not so much dragged against as compressed northwards against a pre-existing fault. If this were so, the amount of east—west tear movement on the North Lyell

Fault need be only small, of the order of one mile, and no great offset of the Jukes Trough deposits would result. This fits the facts quite well, but so does the second theory which supposes that the structure reulted from a straightforward tearing of about three miles; it ignores the rather obvious correlation of the Crotty Monocline with the Tyndall Fault and requires that the latter was originally echelonned with and lay almost three miles to the east of the former. Then a movement of this distance would align the two echeloned faults and the two basins of the Jukes Trough and give an impression of no movement. There is some evidence in the lithology of the Owen Conglomerate of differing conditions of deposition to the north and south of Lake Margaret, but this could equally well be attributed to the presence in the Tremadocian Epoch of an east—west trough or of a pair of echelonned basins.

Further in favour of a large movement are the regional aspects of the structure; if folds are traced round the Disturbance it seems that the line of the Tyndall Fault should pass into the Comstock Valley and thence into the King Valley, and it would certainly be echelonned with the Crotty Monocline. Again, while it is apparent that the thrust sheets of Mt. Owen have been thrust towards the north-east, and those of Mt. Lyell and Mt. Sedgwick have been thrust in a complementary fashion to the south-west: it is also true, though not so apparent, that this complementary relation extends on a regional scale into the surrounding country. To the east of Mt. Owen the Raglan Range is elevated, while to the west of Mt. Lyell and Mt. Sedgwick there is an elevation of the Howards Plain mass. These uplifts suggest some strong relative tear movement of the country on either side of the disturbance.

Before leaving the Linda Disturbance some comment is required on the locally intense metasomatism which occurs in this zone about a mile north of the Lyell Highway and along the Balaclava and Collingwood Rivers. This metasomatism characteristically converts thick limestones into enormous masses of felted but unschisted actinolite rock, and is associated with sericitisation and sulphide deposition. The metasomatism and mineralisation is Devonian and its significance may be important, for it occurs fifteen miles from Mt. Lyell, and it appears that the zone is mineralised independently of the West Coast Range mineralisation. In particular it may mean that not only does the Lyell mining field lie at the juncture of two major structures, but that it also lies at the intersection of two mineralising structures.

The North-East Faults.

These faults are not analogous nor are they complementary, in a simple fashion, to the north-west structures. They show the following features:—

1. They cut all other structures without deflection.
2. They are vertical faults, sometimes expressed as monoclines, are smooth and arcuate in plan, and sometimes appear to be overthrust.

3. Whereas the north-west striking structures are all low angled thrusts directed to the north-east, the north-east faults are vertical and have a variable direction of throw; there is, however, a very common direction of throw which is to the south-east.
4. The amount and direction of throw on individual faults varies, some faults tend to die out westwards, but the few that persist possibly increase in throw.
5. The faults, even when they have little throw, are lines along which the blocks to either side are tilted, and they appear to coincide with abrupt anticlinal or synclinal axes.
6. The rocks forming the margins of the faults are often intensely buckled and brecciated.
7. The faults are the most consistently mineralised minor faults.
8. The faults are later than any period during which granitising took place.

There are some apparent inconsistencies connected with these faults; if they are tensional, why are they so late and so little related to the other structures? what is the reason for their regional and arcuate pattern, and why do they show apparent compressional features? The age of the faults is not in doubt for their crosscutting relations to the north-west folds are clear at Zeehan as well as in the range, and they clearly post-date the silicification of the Owen Conglomerate, for they are often the site of intense brecciation of the Formation—e.g., at North Lyell and Comstock. At Queenstown they cut porphyry bodies and acted as feeders for pneumatolising solutions which hydrolised and kaolinised the same bodies.

Now, the faults mapped have been observed because they are conspicuous by reason of their size, their pneumatolytic effects, or their mineralisation. There are hundreds of unmapped small faults and joints which have much the same trend but which are unmineralised and inconspicuous. It is probable that many of these were contemporaneous with, and were truly complementary to, the north-west folds, but the fact remains that the larger faults were later than any other tectonic event and were coincident with the final stages of metamorphism; they were not contemporaneous with nor complementary to the greater part of the north-west folding which occurred before silicification of the Owen Conglomerate.

It is difficult to explain the fundamental cause of the lateness of these faults and a partial answer must suffice; it seems that the later stages of orogeny were marked by a decrease in the compressional component of the shearing couple and that this allowed the development of a few large, instead of many small, tensional faults. It will be shown below that the north-south tear faults of the Lyell Shear type were probably little earlier than the north-east faults, and as the former are closely related to the granitising processes of the region it may be that there is a genetic relation between metamorphism and structure. If this is so it becomes possible that the change in the nature of the stresses in the Lower Palaeozoic rocks was not the result of changing forces but of a changing constitution of the crust.

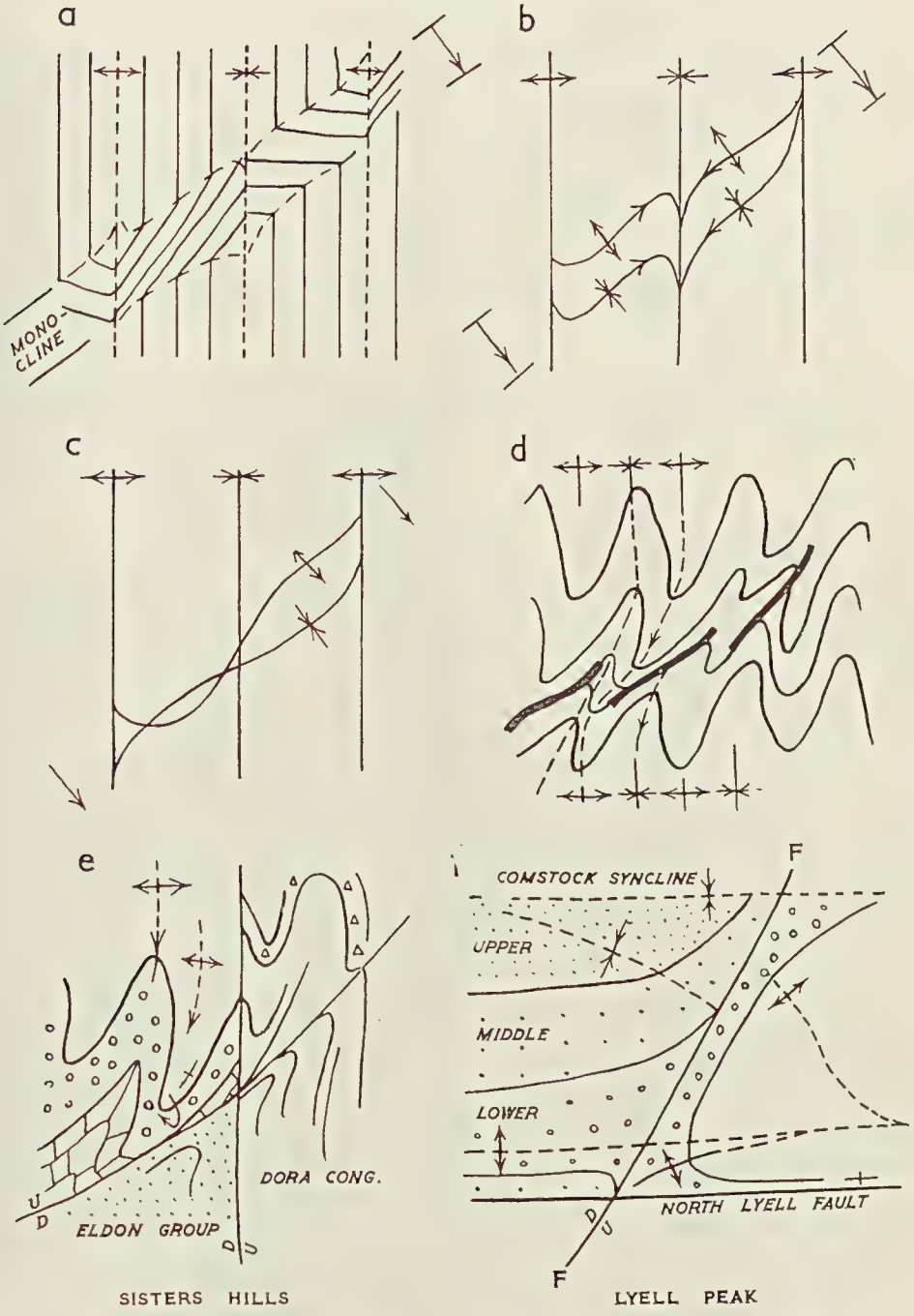

FIG. 8.—To show the effects of oblique superimposition of monoclines on minor folds: (*a*) shows bed traces affected by an artificially angular monocline after peneplanation; (*b*) fold axes set up by a smooth monocline; (*c*) effect of a vertical monocline; (*d*) as for (*c*) but showing bed traces; (*e*) the Sisters Fault; (*f*) east end of Mt. Lyell (diagrammatic).

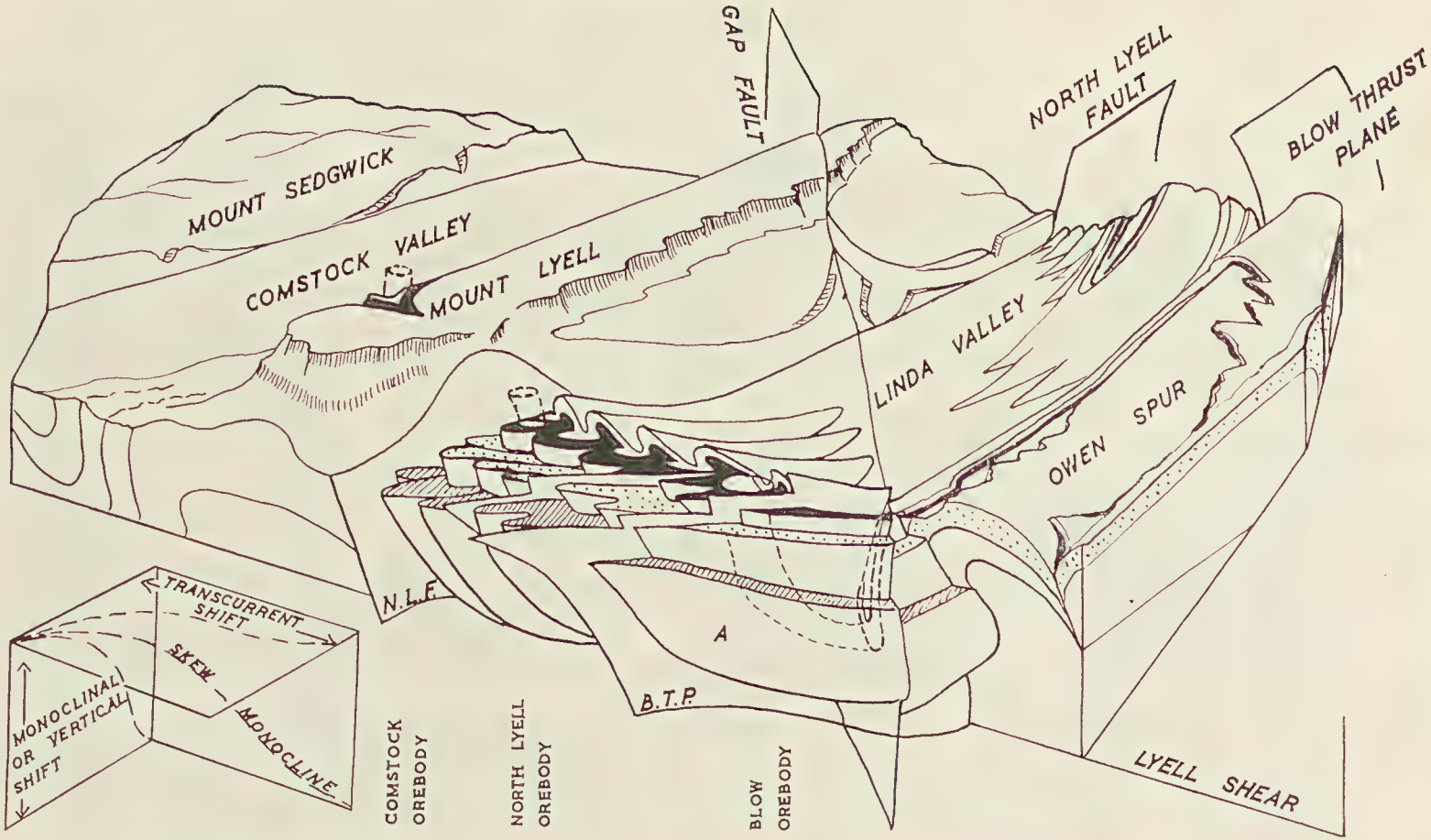

FIG. 9.—To show the effect of the Lyell Shear and the Gap Fault. In ascending succession:—shaded—Low grade ore horizon; dots—Middle Conglomerate; black—Chocolate Shale; overlying the black—Tubicolar Sandstone. The structures shaped like the bows of boats are synclines whose axial planes lean away from the viewer; thus the dips at A are inverted and are apparently towards the viewer.

Apart from the general problem there is the related problem of the regional change of trends of the north-east faults; there is a striking relation between the strike of the faults and the distance from the Tyennan Block. Thus, the faults on the block have a strong tendency to run north-north-east while they swing into an east-north-east direction in the Zeehan Basin. This may be explained by supposing that the old basement was more deeply buried towards the west, i.e., in the deeper part of the geosyncline, and that at greater depths it became more plastic. With rocks which had a low shearing strength, the angle between the shearing force and the tensional cracks would increase and the faults would become more and more westerly in the deeper part of the syncline.

The intense buckling and brecciation which often accompanies the north-east faults are sometimes present on faults like that at the south-east end of Mt. Owen which have no throw; these effects may be attributed to small tear movements but they are more probably due to oscillatory or accommodation movements on the faults.

The occasional overturning of beds along the faults, particularly along the Sisters Fault, is another matter. This fault (plate I), which is probably continuous with the Margaret Fault, is a fault only in depth, for in shallower and less competent strata it is often expressed as a monocline. The cross cutting relation of this and similar faults to the earlier structures is often very complex, for when the monoclinal drag structures are obliquely superimposed on the north-west folds they often create an impression of thrusting and overturning (figs. 8A to 8D). The result of this superimposition is that the dips of the folds and the monocline are vectorially combined, so that the dips with common components are increased while those with opposing components are reduced. This is shown in figure 8A by the deflection of bed traces and in the common case it means that a vertical flexure imposed obliquely on other folds will always cause some overturning of one limb and the reduction of dip in the other (fig. 8C). The overturning creates wholly enclosed structures in which one limb must be squeezed and sheared (fig. 8D) while the flattening of alternate limbs allows a smooth unbroken passage across the monocline. Thus, along the length of the monocline a very slightly echelonned series of thrusts is formed and this gives the effect of a discontinuous fault. Such structures are not uncommon in the region, and somewhat similar faults have been observed by other workers at Lyell, but they are very difficult to visualise and quite impossible to depict without many diagrams; it is for this reason that the example shown in figure 8E is a simplified version of the occurrence at Sisters Hills. It will be noticed that the north—south folds of the diagram are not offset and the fault is not transcurrent, but it may also be observed that the immediate effects are identical with those caused by tear movement.

One of the most interesting of the north-east faults is illustrated in figures 8F and 9. This scissors fault has a westerly downthrow on Mt. Lyell and an easterly downthrow in the Linda Valley. Figure 9 shows how the blocks to either side of the fault have been tilted and figure 8F shows the effects of the pronounced drag on the fault on Mt. Lyell. The throw of the fault must be about 1,500 ft. or more, and it is almost wholly distributed as a monoclinal effect in the adjoining strata so that plunging

folds are formed to either side of the axis of the Mt. Lyell Anticline. On the south side the diagonal folds are clearly drag structures on a fault plane, but in the Comstock Valley the fault, though distinct, is relatively insignificant beside the broad plunging folds. It is assumed that these are the structures which Conolly (1947) shows in his figure 2 and which he has extrapolated to join up with the Comstock Syncline and a Sedgwick Anticline. The writer disagrees with this interpretation and considers that both folds pass into the vastly larger Comstock Syncline. In the succeeding paragraphs it will be shown that Conolly's Sedgwick Anticline is possibly the continuation of the western end of the Mt. Lyell Anticline. In passing, it is noted that the amount of drag on this particular fault is not consistent with the idea that north—east faulting post-dates the silicification of the Owen Conglomerate. It must be allowed that some north-east faulting occurred before silicification, and it may be that the lateness of the tensional north-east faults is due to lateness of the induration of the rocks rather than to a lateness of a particular kind of stress.

The Lyell Shear.

The location of the Lyell Shear is indicated in plate 1; it is a complex dextral tear fault with a variable upthrow to the west and with a highly variable surface expression. Conolly (1947) regards it at Lyell as a 2,000 ft. high monocline, while at South Darwin it is, as first seen by the writer, a sharp syncline; at intermediate points it appears to be a simple tear, and at some places (this is extraordinary for a tear fault) it begins or ceases abruptly. Parts of this fault have been identified by other workers and have been given various names and interpretation, so it is here called the Lyell Shear to avoid confusion. Economically the shear is important, for along its length occur all of the important ore bodies south of Comstock, and it appears that it has not only controlled ore deposition, but has to an appreciable extent commanded the passage of porphyritising and granitising solutions. Fortunately, the structure can be readily dated relative to other processes; it pre-dates mineralisation and granitisation which are always particularly evident along its course; it pre-dates the silicification of the Owen Conglomerate, for it causes rotation of pebbles without their deformation and rarely causes brecciation of that formation; it post-dates the formation of the north-west folds and the Linda Disturbance, both of which it cuts; and by inference it is also later than the main uplift of the anticlinorium. The most intriguing features of the shear are the interplays it makes by combining with the north-west folds, particularly those at Mt. Lyell. These interplays which give the Shear its most specific character are often expressed as intermittent faults similar to those just described for the Sisters Fault, but they are present on a larger scale and are developed to a much greater degree of perfection.

A broad view of the Shear is given in the simplified diagram of figure 10; the north-west folds and the anticlinorium have been flattened out from east to west and the structures formalised. Thus, only one of the several folds between Mt. Lyell and Mt. Owen is shown, and the dragging of those folds is drawn in terms of planes rather than of curved surfaces. The Shear runs as a simple tear from South Darwin

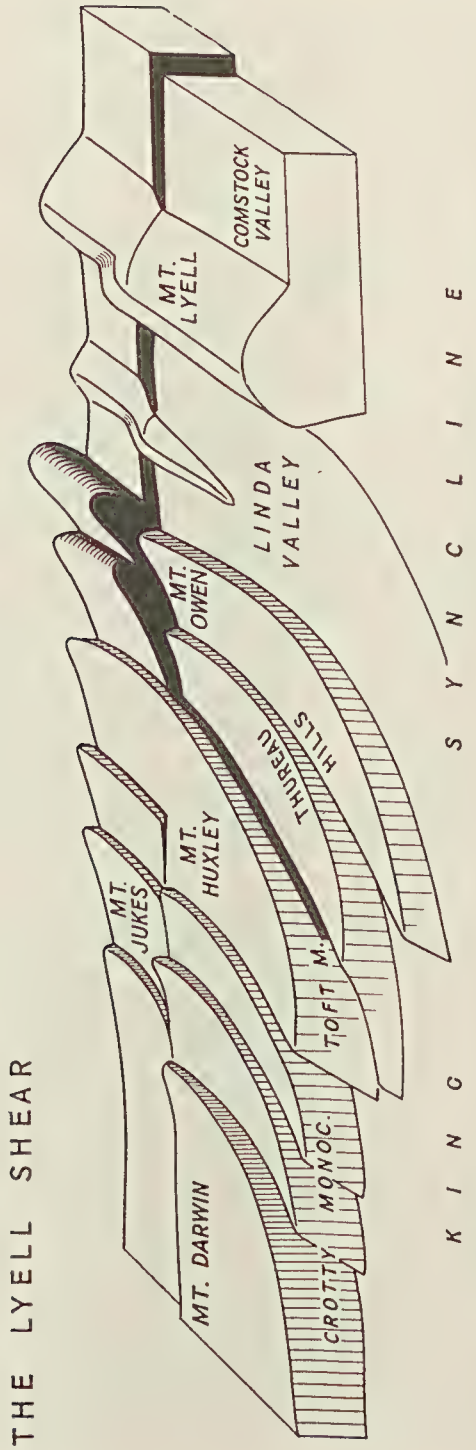

FIG. 10.—The Lyell Shear; the figure is not to scale and the small deflected fold in Linda Valley is only one of several and its west side uplift is four times that shown.

Peak to Mt. Huxley where it passes under the sheet of Owen Conglomerate capping that bluff. At that point it seems that the sheet and a considerable depth of basement has remained unbroken and has moved forward on both sides of the fault. This requires the explanation that the tear movement has been transferred from the Shear to a parallel position, and this is most likely to have been along the Toft Monocline; it also requires that the sheet on the eastern side has been thrust northwards across its immediate neighbour.

To the north the shear is very evident along the face of Mt. Owen but it does not appear to cut Owen Spur; from there it runs intermittently across Linda Valley and at the North Lyell Mine is again interrupted by the great fold of Mt. Lyell. On the northern side of that fold the shear comes in as strong as ever at the Comstock Mine, and from there it may pass on to Mt. Sedgwick and be continuous with the Tyndall Fault, but it has not been clearly recognised north of the mine. It appears that in some way the tear movement has been halted by the Linda Disturbance or by the mass of Mt. Sedgwick and has been partly resolved into a pile of folds; it can be imagined that the block on the west side of the shear has encountered a rigid obstacle and that the north—west folds on that side have been further compressed and thus raised, so that the fault in the vicinity of Mt. Lyell has acquired a considerable west side upthrow. It is, however, impossible to resolve any more than superficial tear movements into uplift of this kind, and the transcurrent movement of the deeper seated Precambrian strata must somehow have persisted northward across the Comstock Valley. It seems probable that the tear movement on the Lyell Shear has been transferred to the Dora Shear (plate I) by the same kind of sidestepping which has already been deduced for the Mt. Huxley area. In this case, however, the sidestepping has been deeper seated and has been permanent, and it is suspected that the new line of movement was determined by an already existing fault.

The local effects of the fault are of great interest and at Lyell Mines the west-side uplift is resolved by dragging of the Owen Conglomerate into the monoclinal effect described by Conolly. A small amount of northward movement was suspected by that writer, but the differential compression of folds on the western side of the shear has not hitherto been considered. It is clear from figure 10 that dextral movement along the fault will cause the north facing thrust folds of Mt. Owen to be compressed and thrust even more to the north. On the other hand it seems that the south facing asymmetric Mt. Lyell Fold will tend to be rotated against itself. Ignoring any drag effects the tendency will be for the Mt. Lyell Fold to be inverted in exactly the opposite sense to what it is on the eastern side of the shear; its northern limb will be inverted, its steep southern limb will be raised to the horizontal, and its north dipping thrust plane will be rotated so that it dips south—i.e., is inverted. This is substantially what seems to happen, but a large part of this effect is due to the uplift on the western side of the fault, and to the remarkable dragging effects which convert the uplift into a vertical monocline; these effects are described in the following detailed accounts.

The Lyell Shear at Lyell Mines.

The ability of the Owen Conglomerate to accommodate itself to every kind of flexing is remarkable, and this undoubtedly accounts for the perfection of the structures seen at Lyell. In that context of intense folding a highly competent body, e.g., the Conglomerate in a silicified condition, would have been completely brecciated, and a less competent bed would have been smeared out, but there was, in the Owen Conglomerate, an unconsolidated formation of pebbles which was relatively competent yet which did not fracture readily. The fine structures of the Linda Valley and at the Lyell Mines have already been described by Conolly (1947), but this treatment is slightly different.

Linda Valley is, as shown in figure 9, a folded trough between the inward facing Owen Spur and the Lyell Folds; the trough is tilted from both ends towards the north-east fault which cuts through the centre and is terminated at its western end by the Lyell Shear. In the example of the Sisters Fault the effect of a monocline cutting obliquely through other folds was to invert and unroll alternate limbs, and on the Lyell Shear we have the same result. At the western end of the valley occur a number of east plunging folds which are exposed as the stripped rock surface of the Tubicolar Sandstone; on the line of the Lyell Shear the sandstones of the northern limbs of the folds are seen to twist to a vertical position, sometimes within a yard and sometimes more gradually, while those of the southern limbs are not at all contorted and may even be re-tilted towards the horizontal. It is stressed that the exposures are in all cases bare rock, and in many cases the structural surfaces are topographic. The upturns are very apparent, for they usually follow a line of haematite metasomatism, but the line of the shear is generally masked because it is also the contact of schist against quartzites. Even so, the bedding and relict beds of the quartzites can sometimes be traced across the contact, and near the North Lyell Mine the bedding in the schists can be observed to swing in an arc, and dips can be seen to pass through the vertical and become inverted. Just as at the Sisters Hills, this effect can be attributed to a monoclinal upturning, but in this case the angle of intersection of the structures is rather obtuse (70°) and because of this the argument of simple upturning just fails to be convincing; in addition, the argument, although it largely explains the observed structures at the mines, is quite inadequate when applied to the large north-west folds of Owen Spur and Mt. Lyell.

On Mt. Lyell the structure is that depicted in figures 11 and 12, and is similar to that drawn by Conolly but with this difference—Conolly continues the axis of the Lyell Fold in a straight line towards the west whereas the writer has swung it through almost 90° towards the Comstock Mine. This may seem to be quite different but it is purely a matter of interpretation, for Conolly's dip observations are much the same as those used here. In effect, it is as if the axis of the Mt. Lyell Fold has been turned clockwise through 90° in a horizontal plane, and the fold has been rotated on its axis through 90° in a vertical plane. Something of this kind has already been attributed to monoclinal warping, but in this case a stereographic study of the angles of dip of the north-west folds along

with the angle of intersection of those folds and the monocline, reveals that no amount of rotation on a north-south axis can result in the near horizontallity of the beds at the western end of Mt. Lyell.

It becomes necessary, then, to advocate an additional mechanism, that a transcurrent element of movement has taken part in the folding. If the dextral strike slip of the Lyell Shear is considered to have been distributed over a wide zone just as the dip slip has been, we should have the effect of a monocline in plan just as we have a monocline in section, and if we consider only the effect of this structure on the original north-west folds it is obvious that those folds would be deflected northwards into the line of the monocline. If we impose the monoclinal rotation on these deflected folds, which are now parallel to the monoclinal axis, it is possible to account for horizontal as well as overturned limbs and so to solve the problems we see in the field.

Before proceeding, however, it should be made clear that the distributed strike shift and dip shift and rotational effects are not separable in fact, but are all attributes of one process. Monoclines are usually regarded as due to movement in a vertical plane normal to the axis, but the process here is one of movement in an inclined plane normal to the fold. The process of warping in an inclined plane, which is probably

FIG. 11.

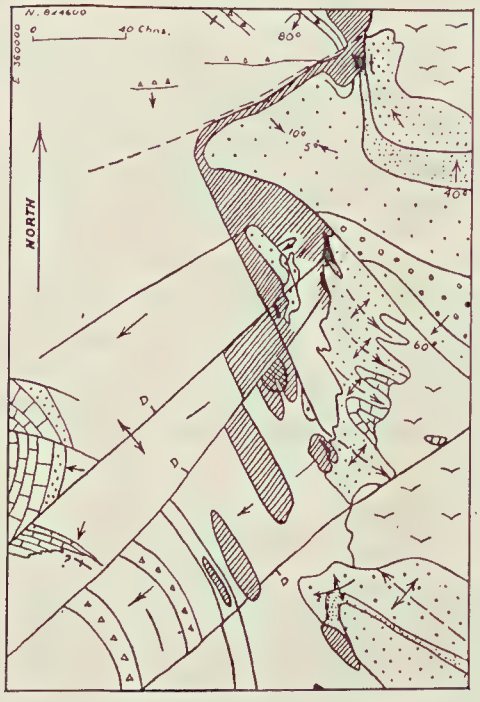

FIG. 12.

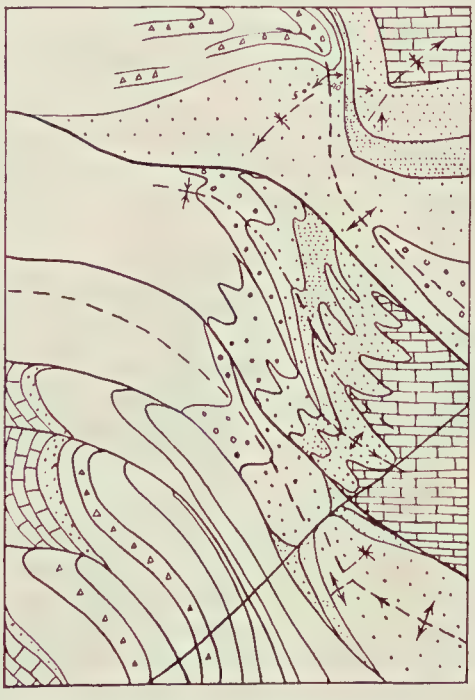

FIG. 11.—Map of the Lyell Mines. The exact shape of the low grade ore is not definable and that shown is in part after Nye *et al.* (1934) and in part interpretative.

FIG. 12.—Reconstruction of the area shown in figure 11 without metamorphism or minor north-east faults.

as common as oblique slip on faults, is here called *skew warping*, and its product is named a *skew monocline*; where recognisable the latter will be a composite structure made of simpler elements, but commonly the skew monocline will be indistinguishable from an ordinary monocline.

The effects of skew warping near the Mt. Lyell Mines is shown in the figures 11 and 12. The second of these shows a reconstruction of the geology without the metamorphic effects or the north-east faults. To avoid too great a departure of bed traces from the present forms of outcrops, the map projection surface is not a horizontal surface but a plane which has been bent along a north-south axis to conform roughly with the surface profile of an east-west cross section through the Lyell Mines. The map is purely interpretative of the information given on the adjacent map, figure 11, of field observations, of strikes and occasional dips in the schists, of the known variation in lithologies and thickness of the Owen Conglomerate, and of the known propensity of the low grade ore to replace beds. On the latter point, the fold forms of the low grade ores are conjectured from the shape of their outcrops in relation to the throws of the north-east faults.

The maps should explain themselves except for some enlargement on the following points:—On examination of figure 12, it should be remembered that the Owen Conglomerate changes in thickness from 1,600 ft. at the mines to less than 100 ft. at the Smelters, and that structurally and on the western side of the area the Dora Conglomerate takes its place (included with the Dora Conglomerate on this map are some Dundas rocks).

In explanation of figure 11 the Owen Conglomerate appears to have been porphyritised or 'eaten back" to its present outline by metamorphism which, along with mineralisation, appears to have been particularly intense along the contact and less intense westward. The residual masses at the Blow and near North Lyell are the most significant features of the map, and the former mass can be projected below ground to where it appeared at the bottom of the Blow Open Cut, while the second mass has been followed extensively in the underground workings of the Tharsis Mine (Conolly, 1947, and Alexander, 1953).

In the block diagram (fig. 9) the development of the topography needs explanation; looking at the southern face of Mt. Lyell it is readily seen that the bedding of the red and white conglomerates passes as a horizontal trace along the length of the escarpment, with only a slight deflection as it crosses the shear, and it is this continuity that suggests that the shear does not continue through Mt. Lyell. With the explanation offered above, it appears to be a special pleading to suggest that erosion has picked the one section line (the present escarpment) which provides the most nearly horizontal beds running across the shear. The reason is simple, for the quartzites when disposed horizontally are highly stable and almost imperishable, whereas when they are inclined they present their greatest weakness to mechanical erosion; they are then reduced or cut back, leaving only the stably disposed horizontal or nearly horizontal beds.

It will be seen that a study of the structure is inextricably involved with this type of geomorphic problem, with metamorphic effects, mineralisation, sedimentary history and regional geology, and that in order to proceed further at Lyell the larger structural picture must be filled in. Before leaving figure 12 attention must be drawn to the close similarity between upturned and blended folds at Lyell, and those of the Main Monocline and north-west folds (fig. 5); since the former upturning was post north-west folding, it may be considered whether the uplifting of the Main Monocline was also late. In view of the earlier history of the geanticline this is most unlikely, but it is noted that any late uplift and dextral movement along the Crotty Monocline would be undetectable.

The Lyell Shear at Mt. Jukes.

To the south of Mt. Lyell Mines the Lyell Shear can be followed for two miles as a line of upturning and of intense metasomatism, but it is not clearly seen again until Lake Jukes is reached. There the Jukes Cirque has been eroded back to a fault plane which now forms its rear wall and the Lake conceals the fault line. To the north and south of the tarn small bornite and chalcopyrite prospects have been opened on the fault line and a westerly downthrow of some 50 ft. is observed. The angle of dip of the fault is within 10° of vertical, but it is not possible to tell its direction. There are no signs of the dragging which occurs at Lyell and there are no other signs of tear movement, but the continuity of the line of haematitic and pyritic deposits to the south and north of this point may signify that only one structure is involved and it seems reasonable to suppose that this would be the Lyell Shear.

The Lyell Shear at South Darwin.

Just west of South Darwin Peak the shear (fig. 13) runs parallel but some distance to the east of the axis of the south plunging anticlinorium, so that a dextral shift on the fault, where there is pronounced drag, creates a sharp anticline and syncline. By itself this arrangement is not conclusive evidence of tearing, for it could be the result of a fault downthrowing to the west. Fortunately, more evidence is available; it happens that to the north of the last structure the adinoles of the Darwin Plateau dip steeply west, and where they are intersected by the shear they are dragged in the same sense as before, forming a synform or synclinal structure in line with the previous anticline and an antiform in line with the previous syncline. This parallel offsetting of beds with opposing dips can be produced by tear or hinge movement but not by simple faulting, so that the fault is clearly a tear or a hinge fault, and in view of the regional setting it is accepted as a tear. The fault has some interesting implications in this particular locality; traversing Mt. Darwin from east to west one passes from the eastern limb of the Main Anticline on to a granitic metamorphic complex which is structurally still conformable, and then one continues on to westerly dipping adinoles which are at least broadly concordant with the granite. These adinoles are probably in their correct sequence, and they are most probably Dundas Group slates overturned. If they are overturned the antiform and

synform structures in these beds can be readily explained as inverted syncline and inverted anticline respectively, and their apparently anomalous alignment with the first mentioned folds is seen to be a normal one.

This zone of contortions, of shearing and of mineralisation is the crucial area of the earlier argument on the metamorphic " unconformity ", it is the sharp syncline at South Darwin which preserves the controversial unconformity, and it is the inverted anticline in the adinoles which carries the wholly inadequate amount of haematite and magnetite which might conceivably contribute to the " unconformable " breccia. In the Owen Conglomerate there are some pyritic and haematitic veins which are clearly Devonian and which, along with the magnetite pebbles of the breccia and magnetite veins of the adinoles, are immediately associated with the Lyell Shear; because of the restricted occurrences of the iron ores it is economical of hypotheses to suppose that they were introduced at only one time, i.e., in the Devonian. There is, however, another argument to be considered; it is that if the Lyell Shear has been a line of continuous movement in two orogenies it would be not at all unreasonable to suppose that the same metasomatic phenomena might accompany each set of movements and that the closely associated magnetite and haematite ores do in fact represent the two periods of mineralisation proposed by Hills (1914).

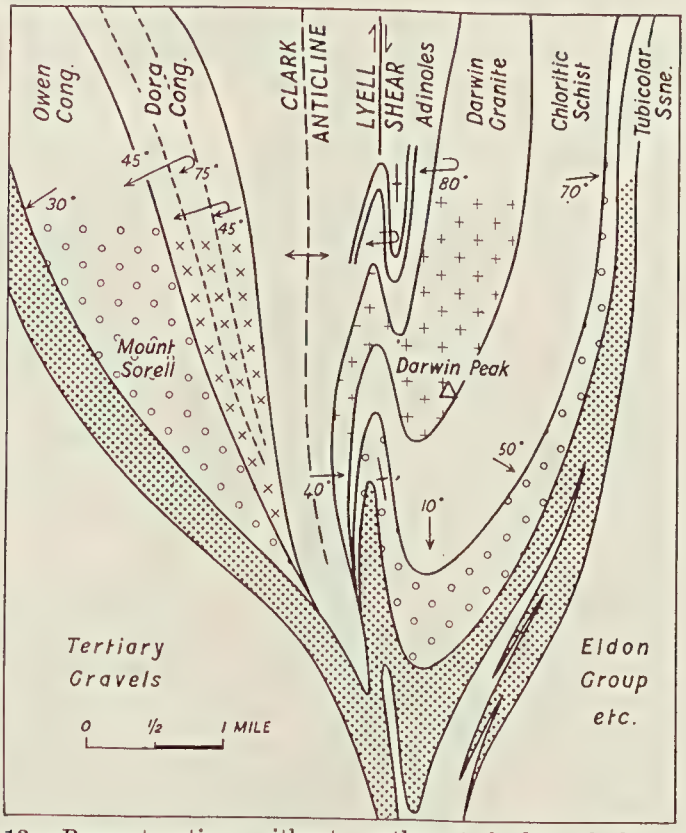

FIG. 13.—Reconstruction, without north-east faults, of the area at the south end of Mt. Darwin and Mt. Sorell.

Finally, although it is difficult to give a reliable estimate of the tear movement on the shear, this tearing may be of the order of 1,000 ft.; any vertical shift on either side of the fault would be difficult to observe and would radically upset this figure.

The Sorell and Clark Anticlines.

Now that the effects of the north-east faults and the Lyell Shear can be allowed for, the major structures and the sedimentary history of the area west of Mt. Darwin can be approached. In the reconstructed area presented in figure 13; the Owen Conglomerate of Mts. Sorell and Darwin thins out markedly towards the nose of the Clark Anticline and on each mountain this conglomerate is underlain by formations which thin out in the same direction. On Mt. Sorell the underlying formation is the Sorell Conglomerate which is composed of granite and magnetite pebbles and on Mt. Darwin there are two formations, a fine grained conglomeratic greywacke and the stratified and conglomeratic Darwin Granite. At the nose of the Clark Anticline only the Tubicolar Sandstone continues round the end of the fold, and it is the lower and conglomeratic portion of the Owen Conglomerate which thins out. In view of the general tendency of the Owen and Dora Conglomerates to have sympathetic variation in thickness it is thus wholly reasonable from a structural standpoint to suppose that the Sorell Conglomerate and Darwin Granite were both originally Dora Conglomerate.

It is now structurally and historically consistent to regard the Clark Anticline as the old Dundas Ridge against which these two formations thinned. The rocks of the core of the Clark Anticline tell very little of their origin, for they consist of thoroughly mixed slates, adinoles, quartz porphyries and quartz sericite schist which cannot be mapped separately or recognised except in the broadest terms. From the large content of slaty and hornfelsic rocks involved, the complex is almost certainly made up of the Dundas Group strata, and the observed strikes of the slates are consistent with the presence of a south plunging anticlinal axis running along the Clark River. From the attitudes of the Mt. Darwin adinoles it may be inferred that the major anticline has an overturned eastern limb but this must be largely due to the Devonian folding and the Cambrian structure must have been a less acute fold. The unconformity at the base of the Dora Conglomerate must, in accord with this thesis, have been less than 60°.

The Sorell Anticline (fig. 6C) follows the general pattern of folds in the region, in that it is an asymmetric fold overturned to the east, but the degree of overturn is greater than usual and the exposure of the structure in the eastern face of Mt. Sorell is also unusual. In that face the three limbs of an overturned anticline and syncline are seen; the horizontal trace of a synclinal axial plane occurs near the base of the cliff or is buried by scree and the trace of the anticlinal axial plane occurs 500 ft. to 600 ft. above. The resultant triplication of the Sorell Conglomerate is not at all obvious as the formation is uniform, and it led Hills to estimate the thickness of the conglomerate as much greater

than is thought here. The 45° and 75° dips given by Hills (1914) show the true situation quite clearly if one interprets his 75° dip as the overturned dip of the central limb.

There is a small anomaly in the thickness of the Owen Conglomerate on Mt. Sorell, for it is found that the formation thins out or becomes sandier in every direction and it must be concluded that the site of the Devonian fold was also the site of a thick accumulation of detritus in Tremadocian time. In brief, the Sorell Overfold is the surface expression of a rejuvenated Cambrian fault in the same way as is the Crotty Monocline, but by comparison it was only a small structure of the Porphyroid Anticlinorium and not a much larger part of the West Coast Range Anticlinorium. It is readily conceived that the Sorell Fault of Cambrian age was echelonned with the ancestral thrust of the Jukes Block and that it was prolonged far to the south as the eastern margin of the Porphyroid Anticlinorium.

The Mt. Read Anticline.

Having discussed the type structures of the southern area it is possible to turn to the less dramatic foldings to the north of the Linda Depression. In this area the third order north-west folds are everywhere, except on Mt. Murchison, very subordinate to the second order folds, and the broad structure is simple. Passing from west to east (plate I) the large folds are the Mt. Read Anticline, Tyndall Fault, Tyndall Anticline, Dora Syncline, Murchison Anticline, Farrell Anticline and Sophia Syncline. Of the first of these very little is known; the others strike 20° west of north except for the last which swings from that bearing to a north-easterly trend.

Mount Read fold, which probably includes several large folds, is known only as an elevated block of porphyroid rocks which extends west from Mt. Read to Mt. Dundas where it includes highly folded Cambrian and Precambrian strata. Where stratification is recognisable the strike of the strata is, in general, north-south and dips are usually in excess of 45°; immediately west of Mt. Tyndall, bedding is clearly displayed in the vertical and north striking conglomeratic quartz porphyries, and though exposures are fair they are so much interrupted by moraine that they lead to no consecutive structural picture. Descending to the Henty River and ascending the slopes leading to Mt. Dundas the country is forest covered, exposures are disconnected and only the rock types can be observed. These are predominantly the breccia and flysch types of South Queenstown; they are locally lightly feldspathised but are generally highly chloritised and do not lend themselves to any system of precise identification or structural mapping. The strata west of the Henty River are probably of the Dundas Group, while those to the east are more strongly conglomeratic or molassic and are probably Dora Conglomerate.

Further north between Red Hills and Mt. Read a section parallel to the last runs for most of the way in quartz and feldspar porphyries which are on the whole massive and give no structural information. On the eastern side of the Henty River the porphyries are again bedded and in the Red Hills area some structures can be followed for 100 yards or more.

The Tyndall Anticline.

This, one of the largest folds of the region, has been mapped for a distance of nine miles from Mt. Sedgwick to Red Hills and consists of a low, almost flat-topped anticline which, along with the neighbouring and similar sized Dora Syncline, forms a full fold with a wavelength of five miles and an amplitude of about 4,000 ft. The fold, which is bordered on its western side by the Tyndall Fault and the upthrust mass of Mt. Read, tends to be thrust to the east and is slightly asymmetric. It is divided by two systems of north-east faults, one at Lake Margaret and another near Lake Julia, into the central horizontal part which forms the Tyndall Range, a north plunging part at Mt. Sedgwick, and a south plunging part at Red Hills. The central part of the fold, built of Owen Conglomerate, has been stripped of its softer cover and the topography generally conforms to its surface, but locally this surface has been deeply carved into cirques which expose the core of the fold and the base of the Owen Conglomerate. The Red Hills and Sedgwick parts of the fold have such plunges that their original protective cover of quartzite passed above the present 4,000 ft. contour and was removed during the Carboniferous peneplanation; the old pre-Permian surface exposed at Mt. Sedgwick still has scattered relics of Permian deposits, but as a rule the Dora Conglomerate and porphyries which form the core of the fold are eroded to well below the level of the adjacent quartzites.

The north-east fault systems which dislocate the anticline are not well defined, for that at Lake Margaret passes below the lake and that at Lake Julia is not easily recognised, for it consists of many branches cutting uniform conglomerate. In a broad view the combined effect of faulting and tilting is clear and is similar at both ends of the anticline. Thus, at Lake Margaret the Gordon Limestone is downthrown about 2,000 ft. below its mean position in the crest of the anticline and two miles to the south, at Sedwick Peak, it must have been raised by at least 2,000 ft. and the tilting must have been of the order of 25°. Similarly, at Red Hills the tilting, though masked by a sub-parallel topography, can be directly observed in the 6° plunge of the fold and at Lake Julia the tilting at the south end of the block may be deduced from the 30° dips in the axial plane of the fold.

The particular interest of the anticline lies in the character of its third order folds which correspond to the north-west folds of the Jukes Anticline. Here the folds trend north 20° west and are not oblique but parallel to the axis of the large anticline. They are best seen in the eastern limb of the anticline on the south-east slopes of Mt. Murchison where they are revealed in stripped surfaces of the Tubicolar Sandstone and are shown to be asymmetric folds with a wavelength of 200 yards and an amplitude of 100 ft. The folds do not thrust towards the north-east as do the north-west folds elsewhere, but face in the opposite direction. This facing is easily rationalised by regarding the folds as drag folds facing towards the axis of the anticline, but this raises the question—are the other north-west folds drag folds also? Those folds are generally rather large to be regarded thus, but this is not a critical objection, and as they are only displayed clearly in the western limb of the anticlinorium their north-east direction of thrust is consistent with their being drag

folds. There are, however, good reasons why they are not typical: their obliquity to the larger fold axes and the fact that they pass downwards into deeper seated strata as thrusts. Although it is conventional to regard drag folds as parallel to their parent fold axes there is no mechanical difficulty to prevent drag folds being formed in an oblique fashion. Convention also allows that the direction of shortening of strata is normal to the fold axis, but this is not necessarily the direction of movement of beds. In the Jukes Anticline and in other folds formed by shearing couples the real direction of shortening of beds may be oblique to the fold axis and the slip of beds will also be in that direction (north-east—south-west for the West Coast Range). Any drag folds will consequently be formed by rotation in that direction and will trend north-west.

The problem is best set out now by asking—are the north-west folds drag folds belonging to a larger fold or is the anticlinorium made up of a large number of smaller echeloned folds? These questions present their own answers. Both large and small folds are integral to each other; they are one compound result of one system of stresses. As far as the Tyndall Range is concerned the reason for parallelism and normality of the "drag" folds is simply that the fold has suffered little compression; its eastern limb has not been overturned to invert the drag folds and the anticline has not been subject to any great shearing stress to upset their parallelism. Why this should be the case as we pass away from the Lyell District is not debated.

The Tyndall Fault.

The Tyndall Fault is best expressed and least equivocal along the foot of the western flank of Mt. Tyndall where it upthrows the vertically bedded conglomeratic quartz porphyries of the Mt. Read Anticline against the west dipping Owen Conglomerate of the Tyndall Anticline. Although the fault line has been excavated and refilled with peat and moraine and the fault is not seen it can best be interpreted in the regional structure as a vertical or slightly thrust fault similar to that which occurs in depth on the Crotty Monocline. The quartz porphyries must, then, represent the monoclinal limb and the quartzites the eastern limb of a sharp asymmetric syncline; this is the "Tyndall Syncline", and the Tyndall Fault is the break along its axial plane.

The downthrowing and tilting effects caused by the north-east faults have already been described in relation to the Tyndall Anticline and these faults must now be considered in relation to the Tyndall Fault. At Lake Julia there are several of these faults, but they may be treated here as one and their effects attributed to the largest of the group. This fault follows Newton Creek, crosses the Tyndall Range and passes on to the Sticht Range. Because the line of the fault has been broadly eroded by ice or weather the fracture is never seen and it is not at first obvious, but the effects of the fault, which must have a throw of more than 1,000 ft., are very conspicuous in the broader view. In the dry lake flat in the core of the Tyndall Anticline, the beds in the south wall of the cirque are seen to be arched and some 300 ft. of the sub-greywacke beds are exposed below the Owen Conglomerate. On the northern side

of the cirque the base of the Owen Conglomerate is not seen, and the formation has a general southward dip, so that there must be a fault running across the lake flat, and it must downthrow to the north for at least 300 ft.

On Newton Creek the field evidence for the fault is quite clear, for the line of the creek is a line of abruptly changing formations; on the north side the Owen Conglomerate and the underlying greywackes of the Julia Hills have a general dip to the south-west and they are folded on axes striking north-west, but on the south side the stratigraphically lower quartz porphyries are vertical and strike north and south.

The effect of the north-east fault on the Tyndall Fault is perplexing, for all of the obvious signs of that major fault disappear. It may pass along the eastern side of the Julia Hills, it may continue northwards past Lake Julia or may continue as an apparently small fault which passes to the north-north-east. This last fault, which is favoured as the continuation of the Tyndall Fault, creates a monoclinal effect in the conglomerates—it downthrows to the east and it dies out rapidly to the north. In accepting this fault as the continuation of the Tyndall Fault one must accept that the latter has the same monoclinal character and is an almost vertical upthrust. If this is so, then the Julia Hills are made of the conglomeratic western or upper side of the monoclinal fold and they owe their existence to the downthrow of the north-east fault on Newton Creek. The Tyndall Syncline is thus a purely superficial effect due to the upthrust and when the fault dies out northwards the syncline must also die out. The Tyndall Fault is now revealed as cutting at a very low angle across the Tyndall Anticline and as being somewhat similar to the Lyell Shear at Lyell.

To the south of the Tyndall Range the course of the Tyndall Fault is uncertain, but if it is to continue in line with its known extent it must cross the track to the Lake Margaret Dam. That it does so is shown by the vertical Owen Conglomerate in the last half mile of the track, but the further southward course of the fault can only be extrapolated. It appears that the north-east fault at Lake Margaret has downthrown the monoclinal structure to the south so that its western and upper limb is again preserved as at the Julia Hills, but this time as the west end of Mt. Sedgwick.

The interpretation which may now be given to the Tyndall Fault is that it has the same origin as the Lyell Shear; it represents a major line of upthrusting of the Porphyroid Anticlinorium and the Tyndall Range consists of deposits of the adjacent trough. The Cambrian fault died out northwards and the Trough must also have shallowed towards Mt. Murchison. At the same time an echelonned fault, the Dora Shear, took up the throw of the Tyndall Fault and became progressively greater towards the north so that a new deep basin was formed on the site of Mt. Farrell.

The southward termination of the Tyndall Fault is as mysterious as the northward continuation of the Lyell Shear, and it is thought that the two may originally have been one. If it is assumed that the Comstock

Syncline, whose trough is never exposed, is an east-west tear fault, then the simple correlation might be made that the two faults represent the rejuvenated upthrust of the Porphyroid Anticlinorium. There is a possible difference between the two, for it seems that the transcurrent movement on the Lyell Shear was not transmitted to the Tyndall Fault, nor was there any great mineralisation along the fault.

The Dora Syncline.

The Dora Syncline must once have been as open and simple as the Tyndall Anticline, but it has been so distorted by late folding and faulting that it is now very obscure. The syncline is most clearly seen to the south of Lake Dora where a ring of inward dipping Owen Conglomerate outlines the core of the fold. The softer Junee strata which formed this core have been removed by a south flowing glacier and have been replaced by tills, but the structure is quite clear. This closed basin owes its existence to the northward tilting which is effective south of the Lake Margaret Fault, and to the monoclinal uplift of the Dora Shear which cuts north—south across the syncline and closes it on its western side. For the moment the Dora Shear may be regarded as a monocline with effects intermediate between those of the Lyell Shear and the Crotty Monocline, or as a zone of mineralised shears, faults and monoclines which downthrow to the east. It is in the contorted central portion of the Dora Syncline that its synclinal structure is vaguest, but further to the north the fold once more becomes apparent in the Owen Conglomerate of Mt. Murchison where it was noted by Reid (1925). The fold is complicated by the small drag folds already discussed, but after allowing for these it appears to be a syncline with limbs dipping at about 45°.

The Murchison Anticline.

Like the Dora Syncline the Murchison Anticline is divided into two parts by the Dora Shear, a northern part of which lies between Mt. Murchison and Mt. Farrell, and a southern part of which occurs at Lake Dora. The fold is highly asymmetric and is thrust to the east on to the Farrell Anticline and the Precambrian massif. In the southern area the thrust plane, which is shown in figure 6B may be regarded as a south-west branch of the Dora Shear and as springing from the shear in the vicinity of Anthony Creek. The minor branch faults shown in the section are not wholly hypothetical, but at least one may be deduced from the map, figure 16C, and it appears to be mineralised with pyrite and copper.

At Lake Dora the anticline is formed of Dora Conglomerate which dips to the west; these dips show a progressive flattening from the west side of the lake, where they are 70°, to the eastern side of the lake, where they are only 20°. This evidence is sufficient to show that the beds in this locality form the western limb of an anticlinal structure and the steeper westerly dips still further to the east are consistent with the presence of an overturned limb there. Along the boundary between the Dora Conglomerate and the Precambrian quartzites of the Sticht Range occurs a narrow strip of pure quartzose conglomerates which

are regarded by the writer as Owen Conglomerate and which dip west at an angle of 50°. These conglomerates lie unconformably on the underlying plicated quartz schists of the range, and as there is no Dora Conglomerate intervening it is concluded that the latter formation thinned and has been overstepped from west to east by the Owen Conglomerate. It is considered that there has been thrusting along the line of overstep and thinning, and that the thick pile of Dora Conglomerates of the Jukes Trough has been thrust on to the old land mass to the east (fig. 6B). Thus the Dora Conglomerate now lies against, and apparently overlies, Owen Conglomerate which rests immediately on the Precambrian. Passing south from the Sticht Range to the Lake Dora area the Owen Conglomerate, which can be traced as a bed overlying the Precambrian schist, has an increasing admixture of non-quartzose detritus and becomes thinner and of finer grade so that it is no longer quite typical of the formation. This is the situation to the east of the lake where a group of disconnected and alternating beds of quartzite and quartzose greywacke lie against the Precambrian quartz schists, and it is at this juncture that a narrow strip of limestone lies between the quartzose beds. The exact relations of the beds are not decipherable, but the limestone is interpreted here as being Gordon Limestone and it is considered as lying in the thrust syncline between the thrust and over-thrust masses (fig. 6B).

Towards the north the anticline is represented by a narrowing strip of schisted and mineralised Dora Conglomerate; at Walfords Peak and alongside Lake Rolleston the western limb and parts of the Owen Conglomerate capping of the anticline is preserved in the third order synclines of the fold. Further north, on Anthony Creek, the anticline is downfaulted to the north by the same Newton fault that is so important in the Tyndall Anticline. At that point the western limb of the fold is brought down so as to expose the Owen Conglomerate once more and the anticlinal strip of Dora beds (schist) is narrowed.

The inaccessible country east of Mt. Murchison was not examined except from a distance of two miles, but it appears to consist exclusively of bare white quartzite hills with none of the low rusty-coloured terrain of the Dora or pyritic schist formations; the structure given in plate I for that area is based on this broad information but is largely extrapolated from the structures to the north and south.

The Murchison Anticline (plate II) is next encountered in the area to the north-east of Mt. Murchison as a block of porphyries and Dundas Slate; the latter dips west at 70° and is apparently isoclinally folded for the outcrop traces the shape of the nose of a large fold. This must be an anticline, for upstream from the Suspension Bridge on the Murchison River there is an inverted sequence which rises to the east until the Owen Conglomerate is met in the gorge. There the structure is well exposed in the cliffs on the south side of the river and the inverted eastern limb of the Murchison Anticline is thrust at an agle of 80° on to the western limb of the Farrell Anticline; there is only a suggestion of a sharp syncline on the thrust between the folds. Downstream from the Suspension Bridge the sequence appears to be upright and the beds dip west at about 45° so that the anticlinal axis must lie just upriver from that point. The anticline presumably runs across the Tullah Flats,

but the evidence for it is restricted to strikes and a few unreliable dips. The steeper limb is, however, clear and it can be traced along the length of Mt. Farrell and it appears that the west dipping beds on the west side of Mt. Farrell must all be uplifted and slightly overturned.

The Farrell Anticline.

This fold is well revealed in the cliffs on the north side of the Murchison Gorge, where its quartzite limbs dip east at 70° and west at 50°. The core of the anticline has been eroded by the Murchison River which has exposed a clean section of the contact zone between the granite and the conglomerate. The contact which, along with the anticlinal axis has been followed for three miles upstream, is seen to be concordant and the trend of the fold is observed to swing from a north 20° west to a north-west direction.

Mapping reveals that the axis of the fold traverses the length of the Murchison River and that it passes into the monocline of Mt. Farrell. This is reminiscent of the passage of the north-west folds of the King Syncline into the Crotty Monocline, but this is the only place where such a passage can be observed and mapped. The map, plate II, shows a number of form lines taken from aerial photographs, and as the beds are nearly vertical these can be regarded as strikes. As the Farrell Anticline plunges to the north the map thus presents an exaggeration of the vertical section across the fold, and it will be seen that the anticline passes into the monocline by the tightening up and diminution of its western limb.

The Sophia Syncline.

The Sophia Syncline is a sharp asymmetric downwarp of the same type as the King Syncline, having at Mt. Farrell the same asymmetry of character of its deposits, the same kind of vertical western limb and the same kind of history. Like the King Syncline it lies between the West Coast Range Anticlinorium and the Tyennan Block, and its Owen and Dora Conglomerates are thick to the west and thin to the east. The fold is for the greater part of its length a horizontal fold which extends for many miles to the north along the Mackintosh River, and is some two miles across at its Owen Conglomerate outcrops. In the Sophia Valley, however, the fold plunges north and as its floor of quartzites rises to the south the axis of the fold swings from a northerly to a north-westerly trend; the syncline then passes out into complex thrusts on the Tyennan Block in the same way as do the minor folds of the King Syncline.

At Mt. Farrell the Owen Conglomerate is of the normal coarse and thick facies encountered elsewhere and it is suggested that it was deposited in a contemporaneously subsiding fault angle depression. Towards the north there is a rapid facies change and the formation, which commonly forms mountains elsewhere, is just shown as a ridge on aerial photographs. There is little doubt that the Jukes Trough existed in the sense of a synclinal structure along the Mackintosh Valley during Tremadocian times and the probable reason for the non-deposition of the quartzites was that the ancient syncline was already filled with Dora Conglomerate and was not actively subsiding. It is likely that there was an adequate supply of quartzitic fill, for this material was supplied in vast amounts

to the same structural basin. It is improbable that in the region to the north the geanticline was actively rising, for the Owen Conglomerate of the Sophia Syncline is uncontaminated by greywacke detritus. It seems probable that the ancestral Sophia Syncline, *i.e.*, the Jukes Trough, shallowed towards the north and any subsidence or uplift had ceased there before Tremadocian time.

Turning now to the south end of the Sophia Syncline, there is again a facies change towards thinner and finer Owen Conglomerate; this is best observed at the south-eastern extremity of Mt. Farrell, where the Formation consists largely of Tubicolar Sandstone which is 400 ft. thick and is interbedded with conglomerate only towards its base. The facies changes suggest that the Sophia Basin was to some extent separate from the rest of the Jukes Trough, perhaps as an isolated deep basin within the trough; this would be consistent with the idea that there was east side subsidence on a fault line beneath the present Farrell Monocline. It will be noted that there is no evidence that the Owen Conglomerate did not exist to the west of Mt. Farrell but it is likely that if the Formation existed in any thickness in that direction some traces of it would remain as synclinal remnants capping hills. These are not found and in the Huskisson Valley where the Gordon Limestone is next encountered to the west no conspicuous signs of the conglomerate can be detected on aerial photographs.

The King-Sophia Synclinorium.

Although they are disconnected the King and Sophia Synclines are continuous in a general sense, for they form the extremities of a much larger synclinorium; this is the King-Sophia Synclinorium which is like the West Coast Range Anticlinorium in that it consists of a series of second and third order folds. The ends of the synclinorium plunge to the north and south away from the centre which is arched along its length in a broad culmination centred near Mt. Murchison. The line of maximum uplift lies along the axis of the Farrell Anticline and this causes the break between the Sophia Syncline and the rest of the major structures.

As previously shown there is some evidence that this break was present in an incipient form during the Tremadocian and it seems probable that the larger second order folds were also in existence then. It is difficult to distinguish the lowest part of the synclinorium in the area of culmination, for the echelonned and thrust nature of the second order synclines means that the lowest part of the synclinorium steps from one depression to the next; in the north the deepest part lies in the Sophia Syncline, but in the south it probably lies along the Tyndall Fault. It is probable, but not certain, that the deepest parts of the Jukes Trough coincided with the structurally lowest parts of the Synclinorium.

The Dora Shear.

The Dora Shear is in many ways analogous to the Lyell Shear; it consists of a number of echelonned faults which run in a fairly straight line from Mt. Sedgwick past Lake Rolleston, along the eastern side of Mt. Murchison and into the monocline of Mt. Farrell. The orientation

of this fault system in the wider fault pattern of the country has been indicated (plate I), and from this the system may reasonably be interpreted as transcurrent; because the faults are almost strike structures it is not possible to demonstrate any tear movements along their length, but there are commonly signs of intense shearing, and the shear pattern, round Lake Dora is so coarse and distinct that it can be easily observed in aerial photographs. The contortion of beds and the common occurrence of monoclinal structures along the line of the shear are readily attributable to overthrusting, but the intense mineralisation and feldspathisation along the length of the line are, in the writer's opinion, strongly suggestive of a transcurrent rather than of a simple thrust fault.

The one important difference between the Dora and Lyell Shears is that while the latter cuts the north-west folds at a high angle and does not branch along them, the former cuts the north 20° west folds at a low angle and tends to run into them. Thus, on Anthony Creek the thrust plane of the Murchison Anticline passes into and becomes indistinguishable from the shear. The shear is best displayed at this point, and on the south end of Mt. Farrell where it has already been described in broad outline, but there are several features of additional interest. The actual fault is difficult to place as there are many sub-parallel faults in a zone; these are easily distinguished for they are mineralised with pyrite and chalcopyrite and have attracted the attention of prospectors. From the Murchison Gorge southwards the line of the shear is almost continuously feldspathised and where the Owen Conglomerate is present there is intense haematisation. The latter is true at Little Farrell and for three miles south and again along Anthony Creek, and many small prospect trenches and adits have been made in both places. In the Dora area there is a widespread dissemination of chalcopyrite in chloritic schists, but this is not strictly localised on the fault line. It may, however, reflect the broadness of the shearing zone in that neighbourhood.

The southward continuation of the more prominent of the Dora group of shears requires mention; from Anthony Creek there are two branches of the shear, one, already discussed, passes to the south-east and the other and main branch passes due south. The latter probably continues under the moraine of Lake Rolleston and runs along the west side of the lake. It is seen to create a sharp synclinal effect in the Owen Conglomerate at the south-west corner of the lake and it continues south to create a vertical monocline (downthrowing east) south-east of Lake Huntley. Aerial photographs show the structure as continuing south again but breaking up into a number of south-east branches. The most southerly and largest of these branches was examined in the area east of Sedgwick Peak and it proves to be a fault which downthrows to the east and sets haematitised Owen Conglomerate against quartz porphyry.

The Mackintosh Shear.

The structure to the north and west of Mt. Farrell is complicated by the entrance of a new factor which cannot be discussed at length, and which forms a convenient limit for this study. On reference to figure 1 or, for preference, to Cary's (1953) figure 3 it will be seen that Mt. Farrell lies at a point where the West Coast Range Anticlinorium

bends round the north-western corner of the Tyennan Block. At one stage the writer was under the impression that the minor structures of the anticlinorium also followed gradually round the bend, but it is not so and the structures proceed in a series of jerks. It has been seen that the movement and mineralisation of the Lyell Shear passes from one echeloned fault to its neighbour and in the end passes to the Dora Shear. The Dora Shear also consists of branches, and so far these have all had much the same trend but now, at Mt. Farrell, the characters of the Dora Shear are transferred to a fault with a different trend. This is the Mackintosh Shear which runs from the sterling Valley Mine for about ten miles in a north 10° east direction. The fault clearly upthrusts the strata on its western side and this motion is responsible for the cutting out of the Owen Conglomerate at the north end of Mt. Farrell. It is obvious that it requires a strike, or near strike, fault to cut out that vertically disposed formation there and this can only happen by the thrusting of the Porphyroid rocks against the much younger strata. As there are no exposures in the alluvium on the east side of the fault it is deduced that the Owen Conglomerate is missing and that the beds there are the Gordon Limestone or even younger Formations.

The convergence of strikes which occurs along the Mackintosh Fault to the north of Mt. Farrell is also found along the southward continuation of the fault on the west side of Mt. Farrell, and at the same time the line is marked by a series of ore bodies. Hall *et al.* (1953, p. 1157) have claimed that the convergence is due to an unconformity which has also controlled faulting and mineralisation, but this does not seem probable to the writer. The continuation of the Mackintosh Fault south of the Sterling Valley Mine is in some doubt and it may continue into the line of the Dora Syncline on Mt. Murchison or continue along the eastern side of that mountain to join up with a known fault with a similar trend at the Gooseneck. The first of these alternatives is preferred and the map is drawn accordingly, but both may be true as shown by dashes on plate I.

Now it can be seen that the Murchison Anticline disappears into the Mackintosh Shear just as the Farrell Anticline disappears into monoclinal limb of the Murchison Anticline, and that the throw of the Mackintosh Shear is compounded of the throws of the two previous folds. Along the Mackintosh River the uplift on the west is considerable and the Owen Conglomerate is not again encountered on the west side of the fault for many miles, and then it is very thin. Instead, and according to Ward (1908), porphyroid, quartz porphyry and granite are encountered along with much the same mineralisation phenomena which are met on the Murchison River.

In the area to the north of Mt. Murchison there is not only the swing of the northerly shears to be considered but also the possible swing of the north-east faults. In this area there is a marked absence of north-east faults but there is a development of west-north-west faults which have much of the characters of north-east faults elsewhere. These are prominent in the lower Murchison Gorge and on Mt. Farrell, and that at the former locality is marked by ore deposition at the Murchison Mine. At the other localities the writer's mapping is inadequate to show

definitely that the faults affect ore deposition at the Mt. Farrell Mines, but there are marked indications in the haematitisation along the faults on the mountain that they may do so.

There is some hesitation in calling these faults simple tension faults for they may be faults with a sinistral movement similar to that which occurs on the North Lyell Fault. In this connection it is possible that there is a weak development of the Linda Disturbance type of structure across the northern end of Mt. Murchison through Rosebery and along the Pieman River. This "Pieman Disturbance" finds support in the map of Carey (1953, p. 1123) which shows that the Pieman River follows a line of east-west trending flexures which have resulted in two instances from the deflection of northerly folds, the Huskisson Syncline and perhaps the Zeehan Basin.

Despite all this the west-north-west faults will be provisionally regarded as tensional and as equivalent to the north-east faults in the Queenstown area. Whether this interpretation applies to the north-east faults crossing the Sophia Syncline is yet another matter and this cannot be decided without further regional information.

The Red Hills Shear.

This is, in reality, not one but a widely spaced group of faults which can be most readily spoken of by reference to the largest member, which is the fault that runs north-north-west from Lake Dora to the Red Hills and beyond. This fault has a north-east downthrow which at the most is of the order of 500 ft. and creates a monocline of this size at its southern end. Near the Red Hills the fault has no downthrow but it is marked by a zone of intense brecciation and resilicification of the Owen Conglomerate and by sporadic pyritisation of the adjacent schists. Some movement on the fault clearly post-dates the first silicification of the Owen Conglomerate and this post-dates the Dora Shear. (The Dora Shear is dated by analogy with the Lyell Shear as pre-silicification.) This dating merely indicates that there was some late movement on the fault and does not exclude the possibility of earlier movement. The late movement does, however, relate the shear to the other late shears and faults of the region and it may be structurally significant. On examination of the structural map of the area the fault is seen to be unrelated to the north 20° west folds, for it is oblique to them and it may well be a branch fault of the Dora Shear. It is analogous to the branch faults of the Livermore area, and like them it may have had a very small dextral tear movement.

The shear may be important in the mineralisation of the area, for although it is not immediately responsible for the Red Hills low grade ore body it is directly associated with the shearing and alteration of the porphyries subjacent to the ore. The line of shearing and chloritisation can be identified at several points along the power line toward Rosebery, where the orientation of the ore body is consistent with the shear being continuous up to that point. This alignment is probably quite fortuitous and it can, at the best, have only a tentative significance in such a highly faulted country.

Structures of the Dundas Orogeny.

Within the area studied there is no direct evidence of the angular relations of the Dundas and Junee strata; what is probably more reliable information than an actual exposure of an unconformable contact is the broad discordance of the two formations as seen in a regional mapping. The east-west cross section (fig. 7) through Mt. Huxley is the best section for showing this relationship, for there the detail of the normally confusing minor structure is well known and can be allowed for. When this is done there is little doubt that the Junee Group lies on the Dundas strata with a discordance of 35° or more.

A second line of evidence is that the Dundas strata rarely present more than one limb, the western, of an anticline. Had the Miners Slate, which is extremely resistant to erosion and metamorphism, been conformable below the Owen Conglomerate and had it not already been indurated it would have been folded with the Owen Conglomerate and should be traceable across the anticlinorium. Of course, the cutting out of the eastern limb of the Porphyroid Anticlinorium may well be attributed to the Devonian upthrusting, but this pre-supposes that the Dundas strata were indurated at that time, and had been folded previously.

The asymmetry of structure which is found in the older rocks is similar to, but more exaggerated than, that of the younger strata, and both are consistent with there having been a vertical upthrusting on the east side of the anticlinoria. In the rocks themselves there are no differences of minor features such as shearing patterns which would indicate that there had been a different direction of compression in Cambrian and Devonian times, and the fact that the Dundas and Junee strata usually dip steeply in the same direction means that the mapping of outcrops can rarely lead to the detection of unconformity.

The real strength of the case for a Tyennan orogeny in this area lies in the palaeogeographic reconstruction which can be made with this orogeny as its basis; the inclusion in the palaeogeographic history of the concept of evolving folds increases the complexity of the reconstruction but makes its critical examination much easier.

Palaeogeography and Evolution of Structure.

The traditional procedure in palaeogeographic reconstruction is to rely on analogies with present day geomorphic expression, but when the reconstruction is of a dynamically altering scene this is obviously difficult. The nearest approach to seeing processes of folding in operation can perhaps be made in the active orogenic belt of New Zealand, where the writer has not only examined late Tertiary and Pleistocene structures of the same type as the Dundas Anticlinorium, but has had the advantage of the experience in this field of Professor C. A. Cotton and other New Zealand geologists. The present-day faulting in New Zealand is well known, but as the extreme recency of pronounced folding and tilting is only now being appreciated even by local workers, some enlargement is made on this point.

The southern shore of the North Island of New Zealand is made up of three peninsulas with intervening bays; reading from west to east the peninsulas correspond to three greywacke anticlinal uplifts, blocks, or masses, of the Wellington District, the Rimatuka Range and the Haurangi Mountains, and the bays are respectively parts of the Hutt and Wairarapa synclinal depressions. The uplifted units have the appearance of asymmetric anticlines with the east limb faulted out and accordingly they appear to be thrust to the east. The fault lines of the Wellington and Rimatuka uplifts are marked at the surface by the scarps of faults which geomorphological studies show to be dextrally transcurrent (Cotton, 1951), and there are many smaller north-west branch faults which are interpreted by the writer as diverging from the main faults into the uplifted blocks. These branch, splinter, or splay faults are the direct analogues of the north-west folds of the West Coast Range Anticlinorium; related splinter faults of the synclinal depressions are naturally obscured by recent deposits, but in the Wairarapa depression some of them are still apparent.

The recency of the uplift of the anticlines is shown by the facts that on the eastern side of the Wairarapa depression the Nukumaruan (possibly Pleistocene) marine limestones and clays dip west at 30° on a wide scale and that, at the Manawatu Gorge on the Wellington uplift similar Pleistocene strata occur to the west and east of the fold and dip at angles of 30° and 80° respectively. In the writer's opinion the late Pleistocene and Recent folding of these strata is similar to, and only slightly less severe than, that of the Owen Conglomerate.

The pre-Cretaceous histories of the greywacke anticlines of New Zealand are generally similar to the earlier history of the Dundas Ridge, and that of the Dun Mountain (Marlborough) Block is comparable in many details. It has the same greywacke strata and slates of a flysch facies, the same lavas, breccias and coarse pyroxenites, and along its boundary thrust at Pepins Island there is an intense feldspathisation and epidotisation which results in syenites very similar to those occurring on the Dora Shear on the Murchison River; the scanty copper mineralisation which is common in the district presents yet another analogy. The Dun Mountain structure, although already ancient, is now only at the stage of the Porphyroid Anticlinorium, and the Pleistocene greywacke conglomerates of the Moutere depression at Nelson are in every detail of context and texture identical with the Dora Conglomerate.

To call the raised blocks of New Zealand asymmetric anticlines is, perhaps, misleading for the most striking feature is not the attenuation but the complete absence of eastern anticlinal limbs. In addition, the western limb is often only gently flexed and the name of "tilted fault block" is quite apt for these structures; the name "fault angle depression" as applied to the lower or synform angle between the vertical ? faults and the surface of the blocks is also apt, but for the corresponding upper or antiform angle which is worn away a name has yet to be invented. The fault blocks are easily visualised as 10-20 miles wide slivers of country divided by major transcurrent faults and continually tilting across their length and in one direction from age to age. Such an image is readily construed when the block is tilted by about 5°, but

when the tilting is 30° in one phase of uplift, as in the Wairarapa, and it is clear that there have been several such uplifts in the Tertiary, or when late Tertiary beds of the synclines are vertical, as sometimes happens, it is very difficult to imagine the tilting as the result of rotation alone. The combined effects of the larger faults and small faults parallel to them, along with the tilting of blocks, results in the kind of isoclinal structure of the Porphyroid Anticlinorium. It must not be imagined that the fault planes have been rotating in this process of tilting, for they are probably nearly vertical, and it cannot be supposed that the beds in the core of the "fold" have been compressed into a smaller bulk. The only possible answer to the problem of tilting is that the core rocks, although of hard greywacke and although shallow-seated, have been squeezed out of their position and it seems that they must have been squeezed upward along the faults in the same way as a piercement sheet of serpentine may have been. Apart from New Zealand there are distinct parallels between the fault angle foldings of the Basin Ranges of the Cordilleran region of North America, the Tertiary folding of California and Colorado, and the Tasmanian structures. Hills (1914, p. 46) first drew attention to the similarity of the sedimentation in the Western American environments and those of the Cambrian of Western Tasmania. The Basin Range structures are discussed by Eardley (1951) who gives an account of the observations which have been made on them, and of the theories which have been put forward to explain them. There is, it seems, much evidence that the faulting is "normal" and that tilting is not due to overthrusting, and Eardley (p. 479) attributes to Nolan the idea that the tilting of blocks is impossible unless accompanied either by widespread shearing or plastic flow at relatively slight depths. Nolan's reasoning appears to be much the same as the writer's, for he considers that the faults of fault angle structures were not normal in the tensional sense but were formed during compression.

In Colorado a structure analogous to that of the West Coast Range is extremely well displayed by the Front Range (Lovering and Goddard, 1947, p. 3). This is shown by figure 14 and by the writing of the authors, who described the eastern margin of the range, which has a north-south trend, as "the locus of many echelon north-westerly folds and persistent steep north-westerly faults. Its structure is dominantly that of a steep monoclinal fold . . . The period of overthrusting (*of north-west folds*)* was followed by north-easterly and east-north-easterly faulting on a large scale throughout the mineral belt during and after the intrusion of the porphyrites that dot it. Many of the mineral deposits are localised at the intersection of the easterly and north-easterly faults with the earlier persistent north-westerly faults where they cross the mineral belt". There are some interesting differences between the Front and West Coast Range structures, which merely serve to emphasise their similarities. The former is greater than the latter but this is, in part, a matter of depth of erosion and the writer has examined only one side and one end of a structure which extends west for 20 miles to Carey's (1953, p. 1115) Rocky Cape Geanticline. The great low angled and subhorizontal thrust sheets and klippe which lie to the west and south of the Front Range structures are nappe structures which this writer supposes have slid from the rising geanticline and have no correlatives

* Writer's insertion.

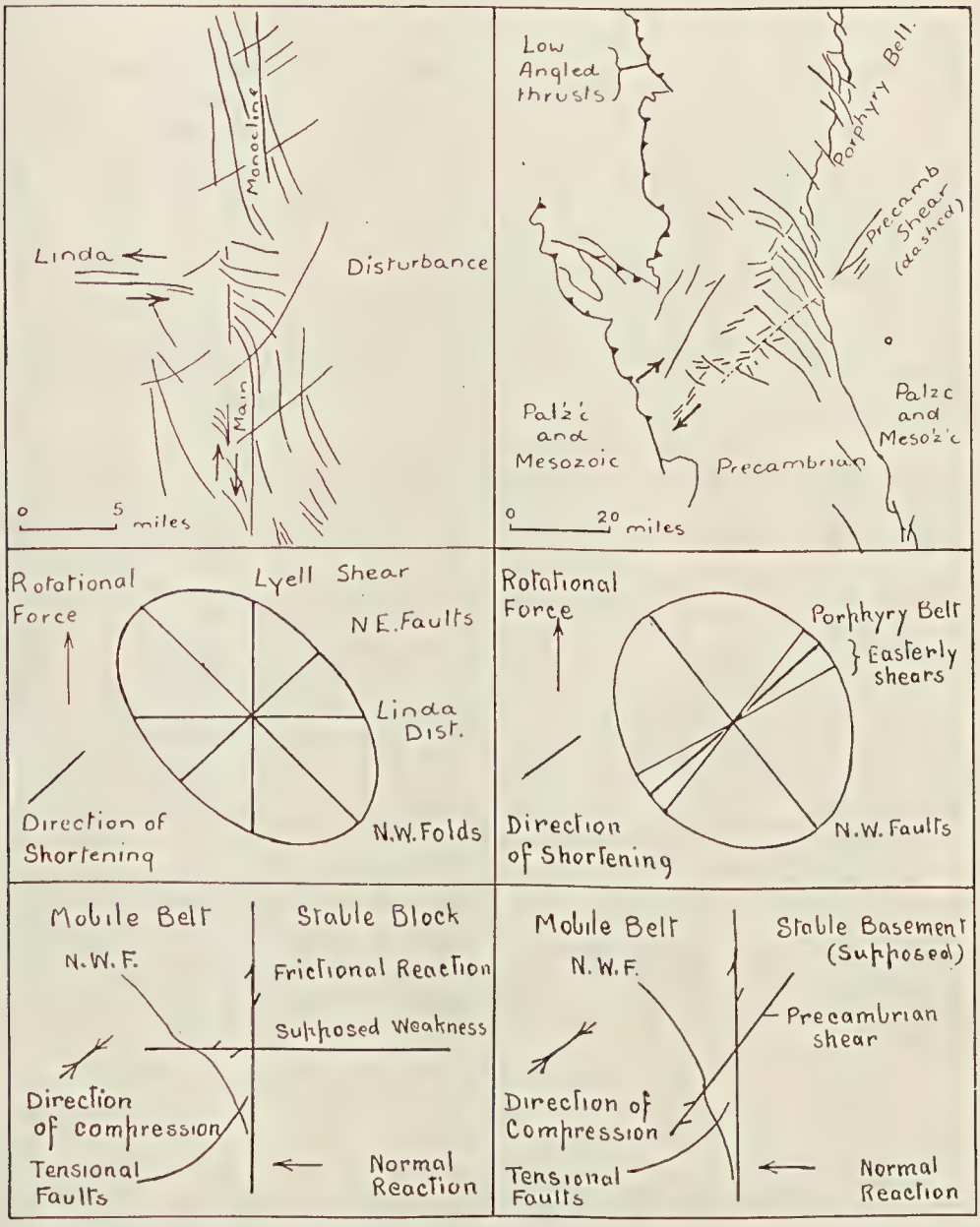

FIG. 14.—To compare the structural patterns and stress environments of (left) the West Coast Range and (right) the Front Range (after Lovering, 1950).

The middle row shows interpretations based on the assumptions that stress is inhomogeneous (rotational) and the crust homogeneous.

The lower diagrams show the compressive force as homogeneous and the crust as inhomogeneous. The compressive force is resolved by weakness in the crust into frictional reaction along the line of weakness and normal reaction perpendicular to that line.

in Tasmania. Figure 14 compares the fault patterns of the two ranges in terms of their stress environments and reveals that the "porphyry" or "mineral" belt of the Front Range is directly comparable in a structural sense with the Lyell-Dora shear system. Lovering and Goddard refer (loc. cit., p. 63) to the easterly faults having been formed in a zone of shearing and tension, and it is probable that the two sets of faults suggested by the diagram are grouped together by the authors. The lower diagrams of figure 14 show a different kind of analysis and that there are some grounds for supposing that the stress system was in part determined by weaknesses in the crust.

The comparison outlined above is valid not only in a spatial sense but also in a time sense, for the Front Range has been a positive element and anticlinorial axis from Cambrian to early Tertiary times. Similarly, the timing of the faulting and metasomatic phenomena are parallel to a degree.

In California the example of Mt. Diablo (Taff, 1935, p. 1098) shows that the idea of solid piercements of ordinary rocks is not new nor without good evidence. The piercing body in the Mt. Diablo region consisted of precisely the same kind of rock assemblage as has already been described for Dun Mountain and the Porphyroid Anticlinorium, and it lies in a similar context of fault angle structures.

In Taff's words "a mass of the Franciscan, subcircular in outline and approximately four miles in diameter, was forced upwards as a fault plug into or through the apex of the structure . . . the upward movement of the Franciscan plug may have been facilitated by erosion from the axial belt of the uplift.". Taff visualises the uplift as the result of a long process of vertical uplifting and tilting of a slice of country and shows (loc. cit., p. 1083) that this resulted in no less than eleven unconformities.

This kind of situation is very similar to that which, in the writer's opinion, exists in New Zealand today and existed in both of the Tasmanian anticlinoria. The main difference between the picture presented by Taff and that held by the writer is that the writer imagines the whole length (not a part) of the core of the anticlinorium as being a piercement structure.

Structural Synthesis.

Carey (1954) has described a rheid or laminar flow mechanism of formation of anticlinal structures at great depths in the more plastic zone of the crust. He supposes that under certain circumstances rocks may flow upwards in a laminar fashion somewhat similar to that of the flow of salt in salt plugs. In his case, however, the flow surfaces are not cylindrical as with salt plugs, but are planar, and the resultant deformation of strata is not domal but anticlinal. Allowing that this thesis is correct, Carey's anticlines are really vast piercement structures of metamorphic rock and they must have had some expression at shallower depths. Such anticlines may even have some showing at the surface of the earth in those regions where orogeny is occurring today.

Carey's type example of a rheid anticline is the Broken Hill Anticlinorium, a complex asymmetric fold (Gustafson, 1950) which bears many resemblances to the West Coast Range Anticlinorium and which may be likened to a vertically attenuated version of that structure. The folding in both regions is of the same order of size and has the same kind of obliquity of minor and major folds; there is a clear parallel between the Main Shear structure of Broken Hill and the Lyell and Dora Shears, and in each case there is the same kind of intense metasomatism and mineralisation. The only material differences of structure which the writer can see are wholly attributable to the deep-seated origin, plasticity, and more attenuated character of the folds at Broken Hill as compared with the West Coast Range, and it is a reasonable extrapolation to assume that the "Range" is underlain by the "Hill" type of structure. If this is accepted and Carey's thesis is adopted, as it will be here, the Porphyroid and West Coast Range Anticlinoria represent the shallow-seated expression of a piercement anticline.

Rheid flow of the more perfect kind exhibited by once deeply buried rocks cannot be expected among shallow-seated rocks with their thin cover and low retaining pressures, and if flow, comparable in any way with rheid flow, exists at shallow depths it must be expressed in the form of numerous shears and faults. The surface expression of piercements of solid rock might be expected to take the form of an exuded heap of structureless rubble, but that idea is presumptive that the process of exudation is rapid; if the piercing were as slow as erosion may be fast then a rock piercement might be no more prominent at the surface than are many salt plugs.

The nature of the shallow-seated "flow planes" can be better understood by reference to figure 7, which shows the passage from plastic rheid folds towards the surface. The deepest of the very highly deformed rocks passes up into a zone of highly plicated or foliated and isoclinally folded strata and that passes into a zone where flowage is along cleavage surfaces. The latter passes up into a near-surface zone where the units of movement are still larger and where small shears and many thrusts carry movement to the surface. In the natural course of events the uppermost zone would not be preserved, for it would commonly form an emergent anticlinal crest and a zone of mechanical weakness which would be rapidly eroded. Alternatively, the hard rocks, which occur in the crests of anticlines and which are capable of being brecciated, must sometimes be buried below some thousands of feet of soft sediments (this was the case in the West Coast Range Anticlinorium) and then the retaining pressures would be sufficient to preclude brecciation of the harder strata which would yield by cleaving.

In accounting for rheid phenomena Carey is not concerned with the ultimate cause of flow, and points out that flow need not be the result of compression; indeed, he demonstrates that some rheid type folds may form in the complete absence of compression. Without disagreeing with this as a general possibility the view adopted here is that upward flow is commonly the result of compression, and that a small part of the arching of very large folds or anticlinoria is the direct result of shortening of strata under horizontal compression; the remainder and biggest part

of folding is indirectly due to compression which operates through a hydrostatic rheid mechanism. The mechanism by which this process might occur merits further discussion.

For the purpose of argument the sialic crust is considered as a more or less rigid layer ten miles thick lying on a heavier and more plastic substratum. In the same sense sialic rocks at a depth of about ten miles generally begin to become plastic, and at a depth of about twenty miles they have no long term strength. If the crust is considered to be folded into anticlines and synclines (no matter how) any small anticlinal loads will be borne by the rigid crust acting as a slab does in engineering practice, and they will be distributed through the isostatically balanced mass by the shearing strength of the rocks. There is patently a limit to the size of anticlinal load or synclinal relief of load which the crust can distribute in this manner, and let us assume that the largest fold that can be supported by the shearing strength of the sial is twenty miles in full wavelength. It would seem that no folds larger than this could exist unless the anticline and syncline were compensated at the base of the sial by a corresponding and respective thickening or thinning of the sial.

This may not be true, for large parts of the crust may be uncompensated by an appreciable, though unknown, amount in excess of the load which the crust can bear when acting as a slab; that is, providing the crust has the structure of an arch or of an anticline measured between two adjacent synclinal troughs (fig. 15). Then a portion, no matter how small, of the anticlinal load may be distributed by thrust on to the synclinal area, and as the syncline has a negative load it will support this thrust. In other words, the compensation of an outsize anticline, anticlinorium or geanticline may, in part, be made by a depression of the sial layer below the neighbouring syncline and not below the anticline.

Because of the strength and thickness of the sial it is probable that there is a lowest possible size for such folds and it is fairly obvious that there must be a maximum size also. That is because the limiting strengths of rocks put a term to the thrusts which arches can bear, and decide the size of folds. Much depends here upon how one regards the strength of the crust; if it is thought to be high then the size of a possible fold increases accordingly but if it is regarded as low then the largest fold can only be a trifle larger than the 20 miles suggested. One might expect variations of both limits depending on a number of unknown factors such as sub-surface temperature and thickness of the crust, but in the writer's opinion the probable limits lie near 15 and 50 miles, which are figures which seem to apply to many of the larger folded or tilted units of the active orogenic belts.

A second qualification of our hypothetical folds concerns the regional stress system in which the folds occur, for it is apparent that the continued existence of an anticline as an arch is dependent on the maintenance of

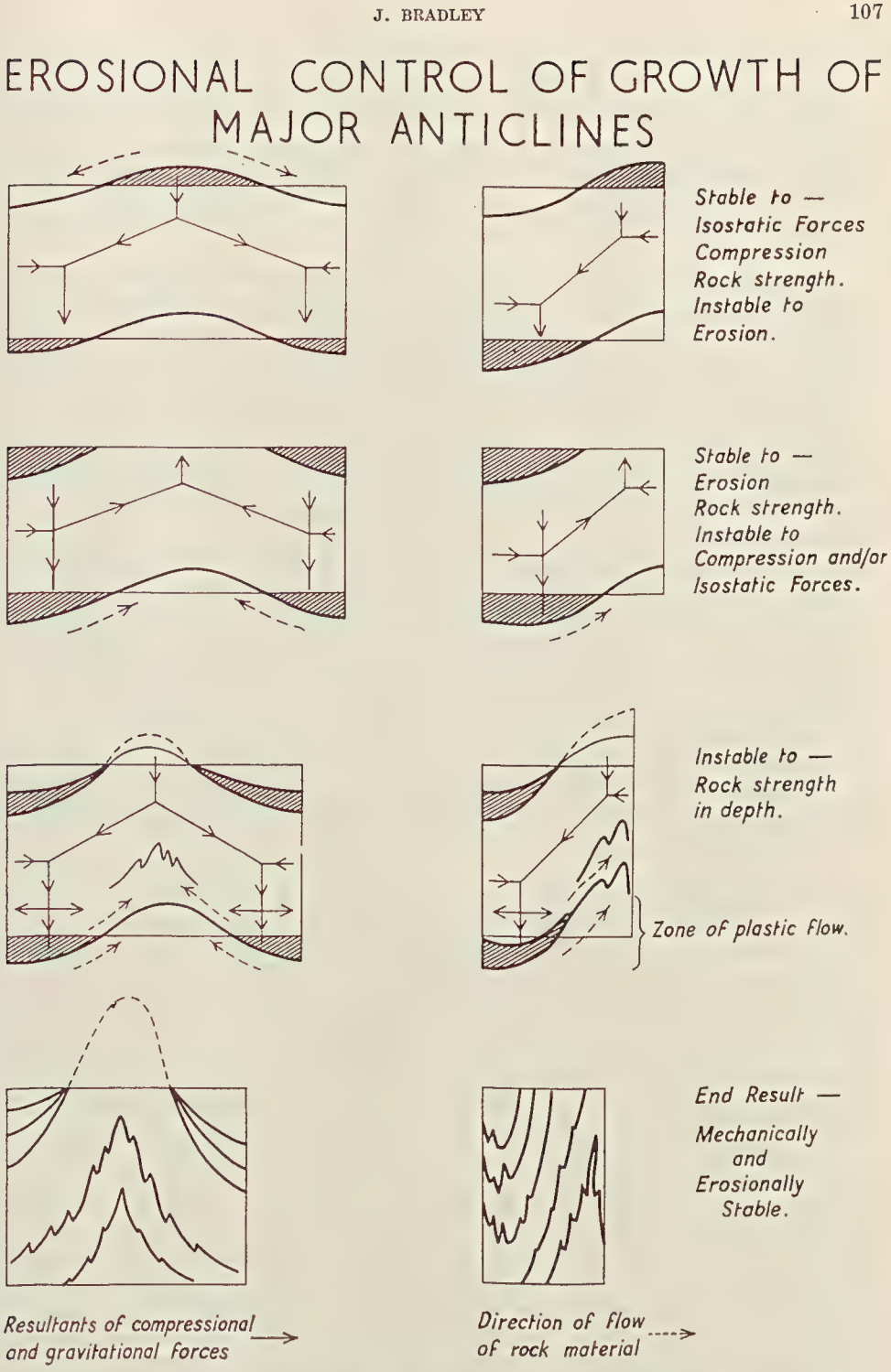
EROSIONAL CONTROL OF GROWTH OF MAJOR ANTICLINES
Stable to — Isostatic Forces Compression Rock strength. Instable to Erosion.
Stable to — Erosion Rock strength. Instable to Compression and/or Isostatic Forces.
Instable to — Rock strength in depth.
Zone of plastic flow.
End Result — Mechanically and Erosionally Stable.
Resultants of compressional and gravitational forces
Direction of flow of rock material

FIG. 15.—The horizontal lines towards the top and bottom of each small diagram represent the mean equilibrium position (of isostatic equilibrium) of the top and bottom of the rigid crust. The thicknesses are not precise but may be taken as 15 to 25 miles and it is assumed that this crust is floating. Shaded parts show the departure from equilibrium caused by arching of the crust.

its buttresses, i.e., of a state of compression. If, for example, it happened that the fold were to be tensed across its axis the anticlinal arch would subside, the syncline would rise, and each would return to its own independent isostatic equilibrium. This second qualification does not mean that the fold must be kept under a state of dynamic compression in order to exist, but it does mean that a static pressure must be maintained once an anticline is raised.

Finally, the arguments which have hitherto been applied to anticlines and synclines are taken to apply equally to fault angle structures. These are sufficiently akin to asymmetric anticlines for most workers to regard them as the same, so there should be no difficulty here, and it may be (it seems empirically probable) that the single limbed structure is more capable than the normal fold in spreading its load from crest to trough.

Now we can consider the history of one of these large faulted anticlines after its inception by compression. Our picture to start with is of an asymmetric fold of, say, 20 miles across and 100 miles long, and with an amplitude of 10,000 ft. and a mean altitude at sea-level; the surface profile is in equilibrium by the interaction of the inherent strength of the structure and isostatic balance. This situation is, of course, not a static one and is dependent on subaerial erosive processes, so that eventually the anticlinal crest must be destroyed and the synclinal trough will be filled. It is easy to see that the syncline will be loaded but it is not obvious that there will be an upward relief of pressure in the anticlinal core. This will be so because erosion will not have materially affected the capacity of the arch to bear load and the effect of erosion is simply to relieve pressure below the anticline. The result of the transference of load must be to cause a differential pressure in the plastic layer in depth, and to allow material to flow from below the syncline into the core of the anticline. If the juncture between the sial and sima is sharp the displaced material will be basic, or if it is gradational the material might be dioritic, but the result will be the same; the land surface over the anticline will rise and the surface over the syncline will fall to their original profiles. In the absence of dynamic compression this process might happen once or perhaps twice but it would cease as soon as the strain on the arch were relieved; i.e., as soon as the sedimentary loading on the syncline began to effect a material subsidence there. With a continued dynamic compression and continued erosion and flow the process would also be continuous and would result in an isoclinal fold or a vertically tilted fault block. It seems probable that in the final stages of tilting the synclinal root would become as plastic as the substratum into which it was depressed and it would tend to flow into the adjacent anticlinal high. Such a flowage would, in a sense, be complementary to the sedimentary loading of the synclinal area and would also tend to halt the process. It could not do so as long as compression was applied and the arch or tilt block had the strength and disposition which would allow an unequal distribution of load. In the final result a region subjected to this kind of folding would consist of large deep asymmetric synclines of lightly metamorphosed rock alternating with sharp anticlines of metamorphosed rocks. Assuming that the fault on which rotation occurred were to tap the solutions available from the heated rocks

in the core of the fold it would follow that the attenuated limb would be a locus of metasomatic activity and mineralisation.

This folding process is essentially one which applies to rocks above or near sea level, and the theory as it is set out above cannot interpret the earlier folding of eugeosynclinal sediments. It does not set out to do so for so far as the West Coast Range and Porphyroid Anticlinoria are concerned neither were folded by the compression and crumpling of soft sediments but were both the result of lifting and tilting, and it is believed that both had a hard basement at no vast depth.

Looking at the process in its surface aspects, what seems to happen is that the tilted block rotates into a vertical position in much the same manner as has already been described for actual cases. On the uplift side there is an upward flow of material adjacent to the fault plane and the crest of the anticline is pushed up again and again. The limb is pushed further out into the syncline and as each cycle of erosion, deposition and uplift occurs, an angular unconformity forms parallel to the strike; as the latest deposits of each cycle are tilted the angles of several unconformities could theoretically add up over a dozen movements to the absurd figure of 180°. At the same time the young deposits of the trough are compressed between the closing fault angle and are squeezed upward and outward on to the low side of the depression. This could explain on the one hand the remarkable occurrence (Hutton, 1939) of a narrow strip of vertical Tertiary deposits caught in the schists of Otago, and show on the other hand (fig. 6B) how the Dora Conglomerate thrusts far over the limestone east of Lake Dora. It shows, too, why the beds along the Dora Shear are indeed sheared, for they lie close in to the fault angle. If it is allowed that the fault plane passes down for, say, 20 miles it is not surprising that the Dundas Geanticline should at one time have been the scene of basic vulcanism and ultrabasic intrusion, or the Dora Shear, Main Shear at Broken Hill and the Nelson Fault, N.Z., be the scene of metasomatic activity.

The process contrasts with the more widely known folding of the Hercynian Appalachians, for that folding occurred only after an ancient basement had been buried for a vast time under a great thickness of young sediments. The folding which eventuated in that instance was more or less plastic and gave rise to smooth fold forms, but in examples where the rigid crust has only a shallow or very young cover the tilt block structure results. This does not mean that thick sediments may not occur in the tilt block setting, but that they must be folded soon after their deposition or at short intervals during their deposition. The tilt block fold may thus be characteristic of orogenic belts subject to relatively continuous movement.

The distinction of the above two fold types was made long since by Gilbert who, according to Willis (1934), described the prevailing fault angle structures of Nevada as "Basin Range" structures, i.e., tilted blocks with vertical faults, and attributed their tilting to a force acting vertically from a source immediately beneath the displaced masses. The Geological Map of North America (Stose, 1946) shows the Basin Range fault blocks to have a mean width of the order of 20 miles, and

it appears that the long and similar fault blocks of the Coast Ranges of California are 25 miles wide (Willis, 1934, p. 233). The major fault blocks of New Zealand are of the same order of size.

In other environments such as occurred in the North West Highlands, the Older Appalachians and Crystalline Massifs of the Alpine foreland the compression of the ancient basements resulted in crustal shortening by overthrusting, but the tilted fault blocks of California and New Zealand do not belong to that category of structures nor presumably to the environment of simple compression. Their environments are distinguished by strong transcurrent movements and it may be that it has been the action of a strong shearing couple which has been effective in determining the general character of the fault blocks. Certainly transcurrent movement would tend to create long straight-sided slivers of country separated by vertical faults and would create vertical planes of weakness along which vertical relief of compression might operate and along which rheid flow might occur. Thus strong shearing forces appear to favour the formation of tilt blocks and it may even be that they are essential to their formation.

Apart from the manner of growth of folds is that of their rejuvenation at a much later date, it might be expected that the growth of folds would be determined by rate of erosion only and that, if this were continuous, orogeny would be continuous also. This is the normal situation, but at least one kind of interruption may occur. It is conceivable that the sub-crust may be more plastic at one time than at another, and that despite a maintained compression, no flow and no tilting would occur. Then the surface would be peneplained and it might even be covered, as was the case of the Tasmanian example, by some few thousands of feet of young sediments. When, at a later date, a softening of the basement happened and flow was resumed, the amount of tilting which occurred would be such that the original surface profile was re-attained.

The hypothesis outlined above has an unexpected application with regard to the inversion of fold movements. If it happens that the condition of peneplanation just described were terminated by a return to plasticity of the sub-crust and at the same time that a tensile force replaced the pressure needed to maintain the fold system, the anticlines would subside. If the region under consideration had been covered by young deposits then there would be formed a syncline over the site of the original anticline and an anticline over the original syncline.

Although the thesis of fault angle folding as expressed so far has no more than a simple relation to the Porphyroid and West Coast Range Anticlinoria it is an important relation nonetheless, and its application to the Lower Palaeozoic foldings solves several problems of structure and sedimentation. In the early days of investigation of the West Coast Range two major problems occupied the thoughts of Tasmanian workers: they were, Where is the unconformity which must lie somewhere between the Dundas and Junee Groups? and, What was the difference between the Tyennan and Tabberabberan foldings? An investigation in 1940-50 of the Dundas Group at Dundas (Elliston, 1954) by a large team of Tasmanian University and other geologists discovered "the" uncon-

formity almost daily but at several horizons. It was not appreciated then that each of several ill-exposed unconformities might be valid; now it seems that not only may they all be correct but that a number of unconformities is consistent in the general environment.

A related problem confronted the writer in determining the relations of the Owen Conglomerate to the Precambrian quartz schists on the slopes of the Sticht Range. Although the conglomerate cannot be interpreted as other than unconformable on the schists the strike of the two formations is not obviously discordant. The Sticht Range participated in the downwarping on the east side of the Jukes Trough and it seems reasonable to suppose that this range also formed part of a tilted block immediately to the east of the Dundas Geanticline. It is probable that this tilted block was at a higher altitude than the geanticline, and it may once have had a thin cover of Cambrian strata, but whatever happened the final effect was that the Owen Conglomerate was deposited on the underlying schists and the Devonian folding has given both the same strike and the same general direction of dip.

The broad structural problems of the region are solved naturally by the thesis, for they form the starting point of the argument which leads up to the final theory. The thesis accounts for the presence of only one limb in the Dundas Anticlinorium while at the same time accounting for the topographic context of the Tremadocian sedimentation. In addition, it explains why the eastern limb of the West Coast Range Anticlinorium should be vertical and only slightly overturned. The asymmetry of the anticlinoria and eastward thrusting of the north-west folds are such that one expects the eastern limb of the anticlinorium to be overturned and it is surprising to see that it is usually vertical. This anomaly now disappears, for the monocline is simply the superficial expression of a vertical fault in the basement rocks and the dip of the western limb is the result of tilting; very little overthrusting need have been involved in the process.

Now to turn to the problem of what happens to the shallow-seated part of the arch of a fold which is raised by extension from inside, i.e., by piercement. There are two cases: in the first, both limbs of the fold become attenuated and sheared and the core of the fold is extruded as a narrow horst. These horsts may be represented by some of the so-called " Taipos " in New Zealand, and the south end of the Rimatuka Anticline has this character: such horsting on a large scale (the full width of the anticline) must terminate the process as it has been set out above, for then an anticline would become a load on the rising piercement, not on the syncline, and would tend to bring the process to a stop. The second case is the general one of fault angle anticlines: the anticlinal core is pushed up along one side of a major fault with the result that the limb of the fold is pushed away from the fault line, and although this will not be apparent the anticline is split open. This explanation may seem like an evasion of the problem of what happens to the arch, but it is the general rule that the top of the fold is missing and it is impossible to know what happens to it. This is well illustrated by the anticline at the Manawatu Gorge, about 60 miles north-east of Wellington City, N.Z., for the soft Pleistocene deposits which ran across it have already

been almost stripped from its crestal surface. If such anticlines have sustained histories it will always happen that the record of any temporary regional subsidence will be removed from the top of the fold and the record of piercement will be obliterated. On the other hand, one might expect that on proceeding across a tilted block he should encounter older and older strata: on the whole this is true, but it is even more probable that he will encounter more and more metamorphosed rocks and that instead of finding recognisable ancient cores he should, if erosion is deep, find granites. Our investigator need not expect to find a gradual metamorphic change, for, apart from strike faulting, it seems most probable that the major fault on which movement has occurred has also been a feeder for solutions which concentrated metamorphism along their length; this may have happened several times.

In view of the erosion of the structures at the crests of anticlines it is unlikely that one could guess at their form were it not for examples such as the West Coast Range where the ultimate stage of uplift was delayed and thick deposits were laid down. Where such formations have been preserved we may look at one phase of movement only and see what can happen to the rocks at the crests of folds. The West Coast Range Anticlinorium shows none of the longitudinal tensional faults which one might expect with a piercement structure, but rather it appears to be a highly compressed fold. If we think only in terms of an east-west cross section the problem is immediately settled, the fold must be the result of compression above and cannot be a piercement. With the additional factor of shearing (strike slip) movement on the north-west faults the opposite solution can be shown to be possible. The same kind of shearing force which caused the formation of the Lyell Shear also caused the north-west fault blocks to rotate in a clockwise direction so that they became more nearly parallel to the main north-south axis, and were stretched along their lengths; this resulted in the development of north-east tensional faults more or less normal to the length of the blocks. The rotation of the blocks out of an oblique line into one more nearly parallel to the main fold must have compressed them across their widths. Although this compression probably added to the already existing north-east thrust component of the north-west folds it does not necessarily mean that the anticlinorium grew in height or narrowed in width at this stage, for the N.-W.—S.E. stretching could conceivably have caused the diminution of the volume and altitude of the fold, and the general effect in the zone of shearing would be that the zone would retain its width.

At the level of the Owen Conglomerate, i.e., at about 5,000 ft. deep, there is no record of deformational stretching, and the tensional movement which is recorded was taken up entirely by the separation of beds. This separation, although very considerable, did not take the form of numerous tensional faults, as it might in weaker or deeper-seated rocks, but was resolved on the relatively few known north-east faults. The extension across these major faults was possibly of the order of 50 yards, but it could not be expressed as gaps of that width; instead, the blocks to either side of the north-east faults tilted to the north-west or south-

east to present wider sections and to take up the "want" in those directions. The amount of tilting of these blocks is thus a direct measure of the amount of separation on faults and, as the mean dip of fault blocks is about 6°, the amount of separation which occurred in the length of the range must add up to about 700 yards.

It is to be observed that this opening on the north-east tensional faults does not necessarily represent all of the stretching which occurred, for it is highly probable that it represents only the stretching which occurred after the silicification of the Owen Conglomerate. Any stretching which was prior to that, and strictly contemporaneous with the Lyell Shear, must have been in unsilicified Owen Conglomerate and would be expressed as distortion, perhaps as monoclines, but not as faulting. This partly explains the lateness of the north-east faults in the Owen and overlying formations, but for the underlying formations it must be assumed that it was feldspathisation, &c., which rendered the rocks rigid. Allowing that the timing of these faults was partly controlled by metamorphism, the fact remains that the north-east faults and the Lyell Shear were the result of a phase of movement different from that which went before. Why this was so is not known, but it is just as probable that it was due to the changing strengths of rocks in depth as that it was due to changing directions of the causal force: it is impossible to disentangle the two.

Now that several structures and aspects of structures have been described, they can be assessed in terms of their relative importance. In the first instance is the question of the strength of the transcurrent component of the regional shearing couple. It is simple to postulate that the couple was applied in a north east-south west direction, but that does not say what was the north-south friction of the crust in a vertical plane (this sets a limit to the shearing couple) nor tell the amount of actual movement which occurred. There was, in fact, relatively little movement in the Tabberabberan orogeny; it cannot have amounted to more than a few hundred or very few thousand feet in a north-south direction. Again, the actual amount of shift tells us little about the shearing force. Relative to the strength of the rocks or the rapidity with which they healed after fracture, the force was slight and barely adequate to cause fracture. This probably accounts for some of the less usual features of the range and, in particular, for the pronounced obliquity of major and minor folds. The degree of obliquity is unusual, but is known elsewhere and is fully as great in a very similar context in the Front Range (Lovering and Goddard, 1950).

This brings us to the next assessment, of the relative importance of drag, tear and thrust movements on the north-west faults; drag in the conventional sense can be ignored, but the other two are difficult to assess. At Mt. Owen, thrusting is due to squeezing rather than over-riding and there may be some strike shift on the fault planes. The thrusts on Mt. Jukes are the surface expression of steep and deep shears and they probably have considerable dextral strike shift. They may, for convenience, be thought of as deep drag shears but are not restricted to a stratum or formation.

The Linda Disturbance is the obstacle which defeats almost any kind of attack; there are classic analogies to this kind of cross structure in the de Bavay Fault at Broken Hill (Gustafson, 1950, p. 1419) and the "porphyry belt" near Denver in the Front Range (Lovering and Goddard, 1950, p. 61). All three are tear structures with shifts of the order of some thousands of feet and are the scene of intense porphyritisation or intensified mineralisation, or perhaps of late phase leaching of porphyries (kaolinisation) and ores (impoverishment). The amount of drag of the north-west folds against the Disturbance is the best index of the shift, but it is much exaggerated by the north-south compression and can be discounted by about half, so that, taken in a general view with relation to other structures, the east shift on the south side is about one mile. The origin of the Disturbance is still obscure but it is certainly as old as any of the Devonian structures.

The best explanation which the writer can devise for the cessation of the Lyell Shear as it crosses the disturbance is as follows:— It is assumed that the geanticline was offset along the line of the Comstock Valley and that any renewed movement along the line of the shear was interrupted in depth by the unbroken mass of Mt. Sedgwick to the north. This tended to halt the shear but it probably did not do so completely, for a fault which may be due to movement on the shear continues on to Mt. Sedgwick. This accounts for a part of the movement and another part must have been resolved into the monoclinal uplift at Lyell, but even together these parts are still very small. The main part of the movement was probably transferred to the whole of the Sedgwick mass, which proceeded to move along the Dora Shear. In between the two shears there must have been a zone of relative north-south tension and this may be reflected in the east-west faults of Mt. Sedgwick, and maybe in the Lake Margaret Fault, but is not otherwise apparent.

If the Lyell Shear, which is not at all deflected in the zone of the Linda Disturbance, actually represents the basement structure, then the twisted folds of Mts. Owen and Lyell must be relatively superficial. As the latter are formed of deposits of the Jukes Trough this is a reasonable conclusion, but a distinction must be drawn between these folds and those which occur on Mt. Jukes and which lie over the shallow-seated bed-rock.

Conclusion.

To avoid confusion, the writer is at some pains to point out that the structures described are not the structures made familiar by text books. They are not the thrust and fold structures known in the Scottish Highlands, the nappes of the Alps nor the folds of the Younger Appalachians, nor are they typical of all of the structures of the mineralised areas of the Canadian, Australian and Baltic Shields. While all of those areas may have been considered at one time or another as typical of present day folded regions at different depths, that is not the writer's opinion. The fault angle type of folding seems to be characteristic of eugeosynclinal environments and to be typical of the Circum-Pacific belt where we can examine it today. It is possible that it is only representative of the later phases of the eugeosynclinal cycle and that an earlier

phase of folding exists, but what that might be is not conjectured. It is considered that this specific type of folding has the following characteristic associations. Its earlier phases are marked by eugeosynclinal sedimentation (greywacke flysch) and basic and ultrabasic intrusion. Its later phases are marked by transcurrent faulting and long continued orogeny with repeated wearing down and rejuvenation. Economically, such mountain belts are metalliferous provinces, and petrologically they may be described as the provinces of porphyries, and pneumatolytic injection. Thus, among older mountain belts of Europe they are typified by the Hercynides rather than by the Caledonides or Alps proper. Neither the rules of tectonics nor of metamorphism of the Alps, Highlands or Appalachians can be simply applied to these belts.

What may be the most important contribution here is not the account of the structure of the West Coast Range Anticlinorium, but the extrapolated structure of the Porphyroid Anticlinorium. This extrapolation is one of structure in time and is comparable to the extrapolation of a section or map into a third dimension. The latter activity can result in satisfying results even where there is only a plan, and is much helped by a few spot heights or dip arrows. The field of this extrapolation has much more than that. Working on the theory that the Devonian and Tyennan orogenies followed the same lines, the structures of the post-Tyennan sediments must represent a subdued version of the present structure of a given horizon in the Cambrian sediments. Accordingly, if the vertical scale of the present structure of figure 5 is exaggerated by, say, two and one half times we should get a picture of the shape of the Cambrian strata. The section showing this (fig. 7) may cause some surprise, particularly when it is advocated as of general application to large parts of the world, but it is claimed that there is as yet no acceptable substitute to this view to explain large scale isoclinal folding in terms of the whole thickness of the crust.

Palaeogeography.

From late Proterozoic to Upper Cambrian time there existed to the west of the Tyennan Block the Dundas Trough or Geosyncline into which many thousands of feet of typical redeposited greywacke sediments were poured. The source of the greywacke detritus may have been distant, but it is possible that some of it was derived from the non-metamorphosed cover of the Tyennan Block, and it may be that some was derived from an island chain to the west. As is common with the deposition of greywackes, there was intermittent spilitic vulcanism and there was at least one phase in the late Cambrian of intrusion of irregular but sill-like pyroxenites. The story of the greywackes, which are monotonous and without good marker beds, cannot be traced in detail, but the very presence of graded beds indicates some earth movement of the country from which the sediments were derived and the vulcanism can be reasonably supposed to have been associated with movement in the geosyncline.

The first folding of the greywackes into a geanticline may have occurred as far back as in the lower Cambrian, but the first definite dating comes from fossil evidence from Dundas (Elliston, 1954) that greywacke deposits there are of upper Mid-Cambrian age and that they were folded in a pre-Tremadocian orogeny. This folding resulted in the emergence of the Dundas Geanticline to form the Dundas Ridge which was at first only a chain of basaltic and trachytic volcanoes, but which gradually grew to form an echelonned chain of hills. The rise of the geanticline was continuous though punctuated by faulting along its eastern side and it was sufficiently fast to maintain the ridge in a youthful geomorphic condition. The coarse detritus derived from the ridge during this phase of uplift was fed into the Zeehan Basin to the west and into the Jukes Trough to the east, and it is probable that periodic faulting and uplift of the geanticline gave rise to many breccias such as those of the Lynch Conglomerates. As the cycle drew to its close it is probable that the low island chain was overstepped at several places like Mt. Sedgwick, but it is probable that further north the ridge was not covered until it was overlapped by the Gordon Limestone.

The existence of the Dundas Ridge was not ended by a cessation of movement of the geanticline but by a regional warping which caused a subsidence of the geosynclinal region, and an emergence of the Tyennan Block. Under these conditions the ridge remained more or less static at or about sea level and the troughs on either side were deepened to receive the quartzose detritus from the Tyennan Block.

The coarseness and sudden appearance of the breccias at the base of the Owen Conglomerate must mean that the regional warping was accompanied by faulting. As the breccias are in part of greywacke origin it is probable that there were still low fault scarps in the Dundas Ridge, but the absence of any great quantity of greywacke means that there was no mountainous country there. In the Queenstown district the supply of detritus was adequate to keep the subsiding Jukes Trough filled to sea level, but it was not so to the south of Darwin Peak where deeper water existed and limestones were laid down. North of Mt. Murchison conditions were different again and it seems probable that there was neither uplift of the geanticline nor subsidence of the Jukes Trough during the deposition of the Owen Conglomerate, and the country there must have been senile and incapable of supplying coarse detritus to the adjacent basins. The end of the Owen cycle of sedimentation was marked by the cessation of relative movement of the geanticline and trough and by a regional subsidence and a marine transgression which allowed the deposition of the Tubicolar Sandstone across the entire region.

Unfortunately, contemporary movement of the geanticline is usually unrecognisable in the Owen Conglomerate but there is clear evidence of some movement during the deposition of the Tubicolar Sandstone, and it is possible that there were small movements during the deposition of the limestone and later deposits. The transgression of the limestone seas was cyclic in that it resulted in the deposition of several calcareous bands in the Tubicolar Sandstone and in a rhythmic banding of the lower part of the limestone, but otherwise stable conditions appear to have prevailed until the deep sea regressed towards the south in the lower

Silurian. Then the region was once more raised to near sea level and the Crotty Sandstone was deposited under conditions very similar to those prevailing during the deposition of the Tubicolar Sandstone. It is possible that the Crotty Sandstone passes out to the south as does the Tubicolar Sandstone, and that the limestone seas to the south of Mt. Darwin were in existence long after the seas to the north had shallowed. It is difficult to guess at the origin of the material of the Crotty Quartzites but the small unconformity at the base of the formation in the Zeehan district suggests two possible sources. It is possible that the regional uplift caused contemporaneous erosion of the limestone over the Tyennan Block and that the Crotty Sandstone consists of reworked Tubicolar Sandstone and new basement detritus, and it is also possible that there was some uplift of the geanticline and again reworking of the earlier deposits. A third possibility is that somewhere to the east of the Range the limestone thins out altogether, so that the Crotty and Tubicolar quartzites are in juxtaposition. It is possible that all of these conditions prevailed, but there was certainly no great movement of any kind during this period.

The lithology and ecology of the Eldon sediments indicates the kind of movement and conditions which must have prevailed during Siluro-Devonian times; these were gentle oscillations of sea level and alternating deposition of silts, muds and calcareous sandstones. The detail of the Eldon environment and the timing of the Devonian fold movements are a matter for the palaeontologist, but the general story seems to be a simple one of shelf sea sedimentation at no vast distance from a low-lying land.

Structural Relations of Ore Bodies.

Accounts of individual ore bodies of the region have already been given by Ward (1908), Hills (1914), Nye, Blake, Henderson (1934) and Conolly (1947), and the writer is not in a position to add to these. This account does not seek to describe ore bodies nor to evaluate them, but rather to relate them to each other and to their broad structural environment. As ores are only special rock types it is convenient to describe certain rocks in the same relation at the same time. Apart from a few suggestions, the detailed description of rocks and ores and an account of their origins will be delayed to Part 3.

The distribution of some selected but representative and significant prospects in the West Coast Range is shown by the figures on Plate I and a catalogue of these (largely drawn from the authors quoted) reads from north to south as follows:—

1. *Mackintosh Copper* (Ward, 1908, p. 86). This deposit lies off the map but is included for completeness. It lies 5 miles north of Tullah. The deposit of copper and lead sulphides occurs in north-south shears and consists of diffuse veins in partly silicified chloritic schist and slate and has been worked to a limited extent.

2. *The Mt. Farrell Mining Company* (Ward, 1908, p. 73). These extensive deposits of silver lead are continuous with the last through a series of minor deposits. They occupy a number of sheared veins at the juncture of chloritised greywacke (Dora Conglomerate) and slates.

3. *The Murchison River Silver and Lead Company* (Ward, 1908, p. 79). In the general zone of the Mackintosh Shear this deposit is continuous with the last, but it strikes rather more east of north, 25° east instead of 10° east. The deposit of galena, blende and pyrite, which was worked for some time, occurs in feldspathised Dora Conglomerate, and as the replacement of these beds is preferential it gives the impression of irregular sills of syenite as noted by Ward (loc. cit.). The syenite is not at all sericitised but is fresh and translucent like many trachytes. The mine is situated at the intersection of a tensional fault with the main shear zone (plate II); the fault, which is of great throw, is marked by the line of the Lower Murchison Gorge, and is typical of the north-east tensional faults further south. The map shows that it has a broad monoclinal effect which influences the Farrell folds. As the zone downthrows to the north the Sophia Syncline consequently widens and the Farrell Anticline narrows, and it also happens that the blocks of country to the north and south of the fault are differentially tilted.

4. *Miscellaneous.* Continuing south from the last is a system of north-west trending veins of galena which lie in Dora Conglomerate and Farrell Slate around the boundary of the porphyritised and granitised mass of the Murchison River. This system, which is still on the Mackintosh Shear, terminates in the Sterling Valley Mine (Ward, p. 197). The line is one of intense silicification of the slates and chloritic schists and this results in a quartz blow sometimes a chain or more wide. None of the mineral deposits have proved to be more than prospects.

5. *Murchison River Copper and Iron Prospects.* Along the Murchison River and around the granite there are a number of poor prospects which are contact veins of pyrite and chalcopyrite and massive replacements of haematite. On the contact small baryte stringers run into the haematitised rock and a two foot vein of baryte is recorded by Ward as running north 20° west; this occurs in quartz porphyries.

6. *Miscellaneous.* Small galena shows occur in the limestone of the Sophia Valley, at the bridge in the centre of the valley, and near the contact between the granite and Owen Conglomerate along the eastern side of the valley. Particular prospects occur in the limestone at White Hawk Creek just to the north of the map and on the Sophia River.

It is to be observed that the district north of Mt. Murchison is characterised by galena with some zinc and a little copper and by granite rather than quartz porphyries. There is a very clear relation between the incoming of the quartz porphyries and granite of the Murchison River and the incoming of copper and haematite there and this arrangement shows an excellent example of zoning. In general, the lead ores are richest along the line of the Mackintosh Shear but are not confined to it, and they are usually associated with relatively unsericitised feldspar porphyries. So far as the character of the veins is concerned there does not seem to be any great preference for ore deposition on easterly tension faults, and most veins are on northerly shears. To the south of the Farrell Mining Field the situation changes completely and the feldspar porphyries are usually highly sericitised or give way to quartz porphyries. The ores are, with few exceptions, of copper, pyrite is abundant, and it is to be observed that granite is never the contact rock of disseminated copper ores.

7. *The Red Hills Prospect.* Figure 16A shows the mode of occurrence at this deposit which is clearly stratiform and in the field is a massive chlorite rock. It is almost certainly a chlorite pyrite replacement of an argillaceous rock but so uniform is it that no trace of its origin remains. Its relation to the overlying and underlying sericitised nodular feldspar porphyries was described in Part I and seeds no amplification. The ore, according to Blake (1939) contains less than 0·5 per cent Cu, and apart from that is of too scanty an amount to warrant low grade working. The usual copper mineral is chalcopyrite and the only other is bornite which occurs in small quartz veins some distance away from the main body alongside the Red Hills Shear.

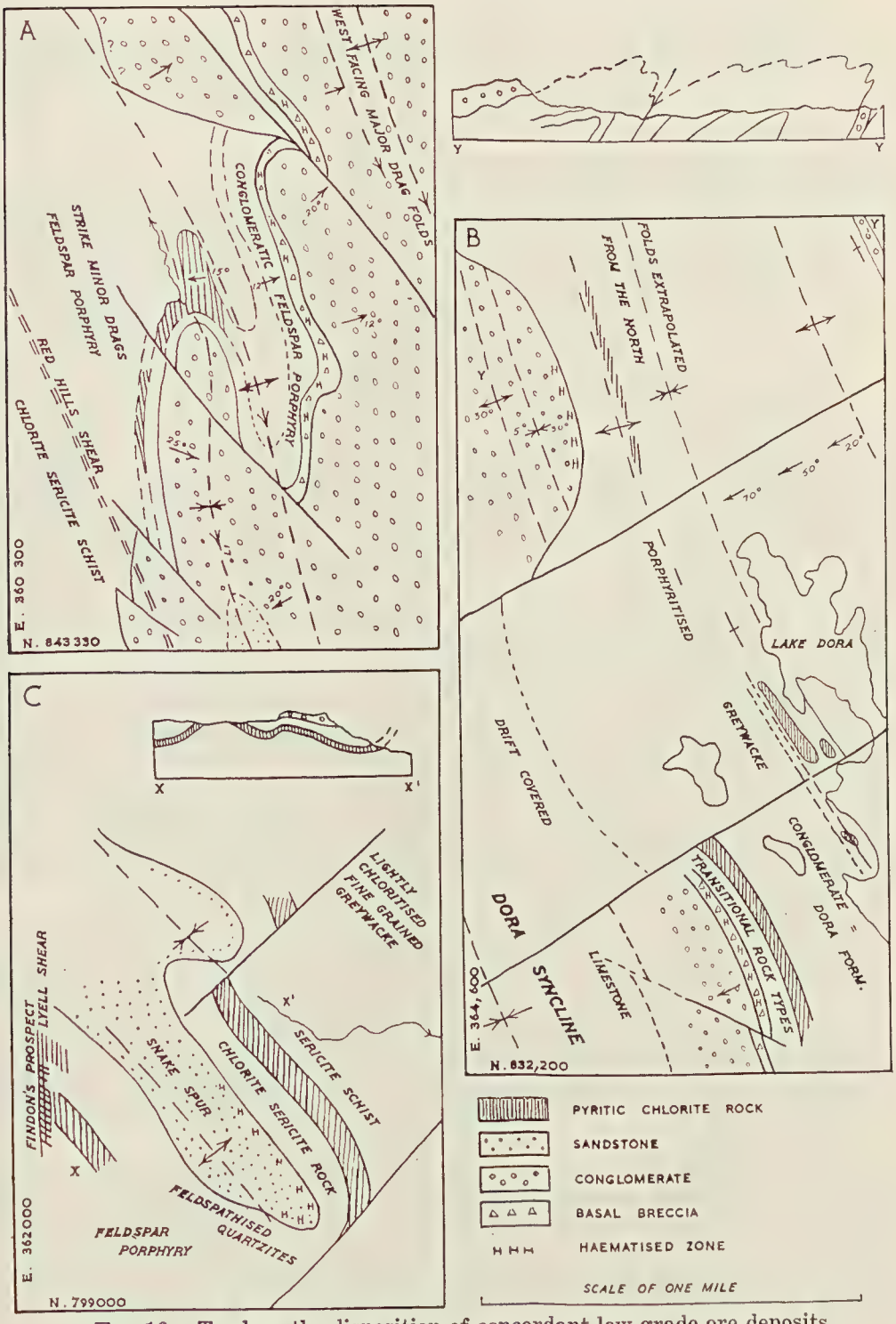

FIG. 16.—To show the disposition of concordant low grade ore deposits at (*a*) Red Hills; (*b*) Darwin; (*c*) Lake Dora. The grids are for reference to Plate I and are approximate.

8. *Miscellaneous.* These prospects occur in sericite chlorite schists running along the Dora Shear and none are large enough to have justified more than trenching or the driving of small adits. The zone is long and continuous and consists of a weak dissemination of pyrite and chalcopyrite in sericite and chlorite rock. It is generally impossible to tell what the parent rock was and the best estimate in view of the environment is that the country was originally greywacke.

9. *Tyndall copper.* Prospects in this vicinity are poor and so far as could be seen consist of very thin pyritic disseminations in a narrow zone along the contact of the quartz porphyries and basal strata of the Owen Conglomerate. In this vicinity the latter are quartzose greywackes and are transitional between the Owen and Dora Conglomerates, and the metamorphism also tends to be transitional so that no sharp contacts are seen. While in this neighbourhood it is worthy of notice that the Tyndall Fault which brings quartz porphyry in contact with Owen Conglomerate marks the only such juncture known to the writer where there is no trace of blue haematite staining of the conglomerate.

10. *Lake Dora Copper Prospects.* Figure 16B shows that these deposits are very similar to the Red Hills bodies, and though there is some doubt as to the structure in the central part of the area there is a strong suggestion that all of the deposits are "bedded", and perhaps all occur below a contact.

The known contact ore is again probably a replacement of an argillite or may be of a tuff and again consists almost exclusively of massive chlorite and pyrite. Blake (1939) gives the copper content of the richest portions beside the lake as less than 0·5 per cent Cu. The associated country rock of this locality is a fresh and highly conglomeratic quartz porphyry and no feldspar porphyries are to be seen anywhere around. The most massive, or least conglomeratic looking, of the porphyries occurs along the southernmost of the north-east faults, and the most intensively prospected of the ores and the most highly haematitised part of the Owen Conglomerate also occur there. There is a strong suggestion that the north-east fault, which is one of the Lake Margaret system, has to some extent controlled the deposition of ore and the formation of quartz porphyry as well; this seems to contradict the view already expressed that the north-east faults are later than granitising processes. The Dora deposits do not lie on the Dora Shear but at a small distance from it, and like the Red Hills deposits they lie quite close to a north-west fault which can be construed as a branch fault of the shear.

11. *Zeehan Road Barytes Prospects.* These two deposits are north-east trending veins of barren barytes which vary in thickness from two to ten feet. The filling is on the whole of massive spar but is in a small part of clear crystal in vughs. The walls of the veins are sharp and the country is of feldspathised and unsericitised Dora Conglomerate. It is concluded that the fissure is tensional and that the deposits are low temperature formations of late origin.

12. *Sisters Hills.* The Sisters Fault is another north-east fault mineralised with galena which is reported by prospectors from the limestone on the Henty River and which has been seen as linings of small vughs alongside the fault at Sisters Hills.

At the time of the drawing up of the Yolande Sheet the writer was unaware of the full significance of the Sisters structures and of the existence of the Lake Margaret Fault, and he continued the Sisters Fault along one of the echeloned shears (see Yolande Map Sheet, Bradley, 1954). With the new knowledge, the Sisters Fault can now be re-interpreted as continuous with the Lake Margaret Fault as shown in Plate I, and this also serves to explain the outcrops mapped on the Yolande Sheet.

Passing now to the prospects associated with the Lyell Shear, a reverse procedure to that adopted so far will be used and prospects will be enumerated from the south northwards, so that we can finish up at Lyell.

13. *South Darwin Prospects.* Along the Lyell Shear at South Darwin Peak occurs a large number of very indifferent haematite and copper prospects. About a mile to the south-west of the peak a typical concordant pyritised contact occurs between the Darwin Granite and the Owen Conglomerate and the rocks over the contact are haematitised. Proceeding north along the shear and passing down below the contact the haematite gives way to magnetite in the adinoles of figure 13; at that point the amount of sulphides visible to the writer was very small and appeared to be located in small irregular stringers of blue-green chlorite and quartz. To the south-east of Darwin Peak some lead sulphides are reported to occur in the limestones there (Hills, pers. comm.) and there are some faint showings of galena in the railway track cuttings near the nine mile post.

On the broad plateau of Mt. Darwin, which consists largely of feldspar porphyry, there are many sporadic and irregular veins of haematite, and if these can be used as a guide to the nearness of contacts it appears that the Owen Conglomerate has only recently been removed from the top of the mountain. The veins carry some copper sulphide but are very irregular and, in these days of dear labour and relatively cheap open cut working of low grade ores, they have lost the importance given to them by earlier workers.

14. *Darwin Low Grade Ore.* From the modern point of view the first really promising prospects in the southern half of the range are the low grade bodies around Snake Spur near Darwin (fig. 16B). These tabular bodies are similar again to the Dora and Red Hills bodies, but with the slight difference that they are not of massive chlorite but are in part sericitic. In this case the bodies are closely related to the Lyell Shear and there seems to be some relation of ore deposition to a north-east fault across the end of the spur. This fault is only inferred from the differing degree of alteration to either side and is doubtful. Snake Spur is the only locality in the area where a gradual process of feldspathisation of the quartzites is visible and the relict structures, which Waller (1903) called laminations and attributed to schistosity, probably indicate that replacement was preferential. The same effect was noticed by Hills (1914, p. 131) who states, "A wonderful variety of these rock types are here shown in the relatively short distance of five chains, varying from green chloritic schist to a rock having the appearance of a fissile sandstone. These bands merge imperceptibly one into the other at right angles to their strike".

    Waller described the formation as a lode but he was quite clear that Findon's Lode followed as a tabular body under the capping of the spur to join up with the Darwin low grade ore, and it is surprising that he did not identify it as a stratum. It is difficult to see which is the horizon replaced at Darwin and, despite the fact that the quartzite overlying the ore is probably the Tubicolar Sandstone it is not possible to say that the ore replaces a horizon in the Owen Conglomerate. The beds below the ore horizon are chloritised and fine-grained conglomerates, they are hardly contorted at all and are quite unschisted, so that they appear to be altered greywacke. On seeing what can happen to the quartzites of the spur which are first replaced by feldspar and then by chlorite it is impossible to be definite in the matter. Judging by experience at Lake Dora and Red Hills it is probable that the ore lies fairly close below the Owen Conglomerate which must accordingly be thin at this point.

15. *Barytes Prospect* (Hills, 1914, p. 121). This is an east-west vein of barytes some 3 ft. wide which appears to belong to the north-east tensional fault system and as it occurs in feldspar porphyries it appears to be later than these rocks.

16. *Lake Jukes* (Hills, 1914, p. 117). Between the last occurrence and Lake Jukes several haematitic and pyritic prospects lie close to the line of the Lyell Shear, but it seems that the prospectors who took up the claims were more than ordinarily optimistic even for those days. Even at Lake Jukes, where some thousands of pounds were invested, the showings of ore are, according to Hills, very limited, and he described the ore as sporadic irregular veinlets of bornite. These occur in the quartz feldspar porphyry adjacent to and below the contact with the Owen Conglomerate.

17. *Proprietary Peak* (Hills, 1914, p. 100). This prospect is, like the last, an irregular network of veins too scattered to make a mine and too thin to justify large scale operation; it lies on the line of the Lyell Shear and below the base of the Owen Conglomerate, but it is not a contact body for it is narrow, trends north-south and, according to Hills, it extends in depth; the ore is chalcopyrite and it appears to have been formed in a shear zone.

18. *Mt. Huxley.* Along the eastern side of Mt. Huxley and extending to the Mt. Lyell Mines is a wide sheared zone of feldspathised and chloritised greywacke conglomerate. These are mainly Dora Conglomerate, they are lightly pyritised, and they are indistinguishable from some of the Mt. Lyell schists derived from quartzitic conglomerate. The pyrite in this zone is not associated with the Owen Conglomerate contact, for the present surface must lie below that horizon and the pyrite seems to be a wide dissemination around shear fissures.

19. *Strahan Road Gold Mine.* This prospect is probably typical of many gold bearing veins of the region but it is the only one which can be traced for any distance. The vein can be traced in a south-west direction as a ridge of silicified greywacke from a knoll (361700/815400) to the Strahan road (see Queen River and Owen Map Sheets, Bradley, 1954). Gold prospectors have driven short adits at several points apparently without much success and alongside the road some fairly extensive workings were made. The writer has no reports on this mine, but it was apparently a marginal prospect. The "quartz" from the ridge is a creamy chert and on the whole the quartz of the veins appears to be fine. The vein is obviously one of the north-east faults and looking at prospects generally, there is a fair case for supposing that this orientation of gold veins is common. Hills (1914, p. 121) cites one example on Mt. Darwin which seems to belong to this category and which bears free gold, but in most cases no gold is visible, and in the whole history of the region no gold veins have been mined with success.

20. *Burkes Show.* This is a small galena prospect lying on a north-east fault which can be followed some way toward the West Lyell Mine. The evidence for the fault is very clear, for the quartz porphyry in Queenstown is upthrown in a straight line against the Gordon Limestone and the Crotty Sandstone. This portion of the fault is mineralised with galena for about one mile. As the fault cuts out the limestone at the Sandhill, its throw must be about 1,000 ft., and it is apparent that it must continue across the town for the limestone does not appear between the Eldon Group and the Dora Conglomerate in any east-west section. Near Conglomerate Creek the continuation of the fault is again marked by the cutting off of the limestone and the fault has been extrapolated with few checks from that point to the mines.

21. *Mt. Lyell Mines.* The account which follows is an interpretation of the work of all those who have contributed to the Lyell problem and it is the application of the writer's broad picture to the detailed problem. To make this quite clear a summary will be made of the findings to be drawn from the region. At this stage it will hardly be questioned that the Lyell, Dora and Mackintosh Shears have controlled ore deposition and much silicate metasomatism. Ore is found in the shears of the system and disseminations are associated with both shears and their branch faults. Rather than the shears forming passages for ore solutions rising from the "igneous" bodies, they appear to have provided the solutions which have produced the rocks as well as the ores. Because of its transcurrent character, the Lyell Shear must extend to a great depth and it seems likely that the Dora Shear did likewise and that the solutions they transported were also of deep-seated origin; in the writer's opinion they may rise from 30 miles deep, but there is no need to explore this point here.

The second great control on ore deposition and rock alteration appears to have been stratigraphic and to have been a function of the differing compositions and constitutions of formations. In general, the ores are zoned from copper to lead outward and probably upwards from the lines of the shears, and as these coincide with the attenuated limb of the geanticline the migrating ore solutions tend to accumulate in anticlinal highs. The spreading of metasomatising solutions along porous horizons in chemically uniform rocks tends to produce sill-like bodies of the syenite type at Tullah, and the subsequent upward migration of the solutions must tend to produce fronts of alteration. There seems to be no reason why the same kind of sequence should not occur several times in a vertical succession, but this has not been observed. In the West Coast Range the lateral spread of solutions in the Dora Conglomerate seems to have been general and the formation of upward migrating fronts seems to have resulted. The fronts have apparently been halted by gross changes in the permeability or composition of beds and the front of feldspathising and chloritising appears to have been stopped by the highly permeable and siliceous Owen formation. It may be conceived that the Owen formation was of open texture and that any high temperature and pressure solutions entering it would suffer a change of pressure, and just as geysers deposit their load on meeting the air, they also would deposit their burden of silica. In a chemical sense it is natural that a halt would be caused at the juncture of the formations, for the greywackes are so near in composition to feldspar and quartz porphyry that they would be made over very readily. It is thought that the physico-chemical equilibrium at the contact would influence the precipitation of sulphides and of haematite and so cause the contact ore bodies. There appears to be some tendency for sulphides to replace argillaceous bands, but there is only one example where the original beds can be identifid. That is at the Lyell Mines, and the bed is the Chocolate Shale member of the Owen Conglomerate. The above argument of the growth of fronts applies to the deposition of ore at formation boundaries and along the contacts of concordant porphyries, but it does not exclude the possibility that porphyries might be discordant and ore bodies transgressive.

The role of the north-west folds and faults is our next consideration, and it is apparent that any upward migration of solutions would tend to be controlled by them. Such a canalisation of ore solutions might cause the localising of rich ores, but where the thickness of the ore horizon is greater than the amplitude of the folds the effects will not be quite so marked. In regard to canalisation there is, however, the additional possibility that any deep-seated fault or shear which is expressed toward the surface as a monocline and which cuts minor folds will be expressed as a number of echeloned shears. The location of these will be controlled as at the Sisters Hills, and if the deep-seated fault is a feeder the shears will canalise ore solutions and localise ore deposits.

It has been shown that the north-east faults have some importance in ore deposition; they are tensional, are late, and carry leaching solutions, probably steam under pressure. These solutions have sericitised and kaolinised the feldspars of the porphyries and have deposited the resultant colloidal silica in chalcedonic or cherty veins; they have probably derived their baryte content from the same source, the feldspars, and they have probably taken their gold from the leached ubiquitous pyrite. The deposition of the separate products at different levels in the vein system is another matter. Apart from structural arguments it is evident that leaching is a process subsequent to the formation of low grade ores. The latter are closely associated with feldspathisation and they are therefore regarded as products of anamorphism. When the feldspar porphyries surrounding the low grade bodies are sericitised (they are very nearly kaolinised at times) it is apparent that the ores as well as

the rocks have been subjected to a hydrolising process. When one finds in conjunction with such ore bodies, other and richer ore concentrations which have no associated feldspathisation but are accompanied only by sericitisation it is reasonable to suppose that they have a different origin. There are two possible and related modes of origin of these rich ores, one, which will not be treated here, where stringers of ore moved ahead of the pyritic front (this is the case of the Murchison River copper prospects), and the other where the ore is the result of leaching of low grade bodies; this is the case of the richer bodies at Lyell. The process is the same as has already been detailed—that the solutions emanating from depth during the later phase of metamorphism have leached the ore mineral and have re-deposited it higher in the tensional fault system. The transport of solutions at this stage is a different matter from that during granitisation; it is by channels rather than by diffusion. In this environment solutions are more sensitive to changes of pressure, temperature, and reactive wall rocks than in the granitising stage, so that ores are differentiated and replacement is selective.

The process sketched above is similar to the well-known process of secondary enrichment of ores, except that it occurs at higher temperatures and it must be expected that its products, like the secondary ores, will be characteristic and will be distinguishable from the truly primary ores. In general there must be a wide variation among possible conditions of deposition and the following criteria apply specifically to the circumstances surrounding the genesis of ore in the West Coast Range. The terms primary and secondary have already been pre-empted, so that for convenience and to distinguish the late phase ores from true contact, anamorphic or "frontal" ores, they will be called tele-frontal.

The following guides have been used by the writer to distinguish tele-frontal phenomena:—

1. All quartz or siliceous veins below the quartz haematite front are regarded as tele-frontal.
2. All mass sericitisation or kaolinisation except when very close to or above the haematite front is late; the latter cannot be distinguished as early or late.
3. All bornite which occurs inside the haematite front is late. This is because bornite never appears in dissemination and is, presumably, not a frontal product.

For ore bodies outside the haematite front it is not possible to be quite so definite, but the following are general guides:—

4. Siliceous sulphide bodies are late. Non-siliceous ores may be contemporaneous with granitisation or late.
5. Highly differentiated ores, i.e., large pure masses, are late. Complex ores are possibly early.
6. Gold veins and ores with high gold content are late. Any ore with a concentration of rarer minerals is late.
7. Baryte probably indicates lateness particularly when the veins occur in porphyries.
8. Ores fed by the tensional faults are late—this is probably specific to this locality.
9. Any ore with magnetite is an early product of granitisation.

Now to turn to the Lyell ore bodies; figure 9 shows the writer's picture of the main structure at Mt. Lyell Mines without the confusing north-east faults. The low grade ore is shown as a replacement of the lower portion of the Owen Conglomerate, and though the picture given is thought to be correct in principle it is almost certainly wrong in detail. The illustration is a straight-out extrapolation of known factors but it cannot allow for unpredictable changes which might occur after leaving the known ground of Mt. Owen and Linda Valley. Principle among these factors are the facies changes in the Owen Conglomerate, for it is known that the formation changes thickness abruptly and it is just possible that there are interdigitations of Dora Conglomerate with the Owen Conglomerate at this juncture. Thus, although the structure of a conglomerate bed can be traced across the contact, there is no absolute guarantee that the Lyell schists are necessarily metamorphosed Owen Conglomerate. On the upper side of the contact it is also possible that an interdigitation of greywacke beds into the Owen Conglomerate would be unrecognisable, because the greywacke would be silicified beyond recognition. These fantastic complexities are the inevitable working out of the theory of origin of the West Coast Range structure, and it happens that at one point or another the writer has seen all of these variations. Making allowances for these factors, and apart from Conolly's findings, there is little doubt that the diagram represents the true situation and the low grade ore is a replacement of the Owen Conglomerate.

The Middle Conglomerate member of the formation, which is sandy in parts, has resisted alteration to a sufficient degree to leave substantial relics which are shown in figure 11, and it is the presence of this member which allows the working out of the structure. The Chocolate Shales have been most susceptible to change and it is largely because of the ready schisting of these fine argillaceous beds that the residuals of the Middle Conglomerate have been isolated. The shale has also been particularly favourable to replacement by sulphides and the rich ores at North Lyell, the Blow, and Comstock occurred in it.

Now, it is conceivable that the ore solutions found their way to this horizon through channels along the Blow Thrust Plane, the North Lyell Thrust Plane and along the faulted Comstock Syncline, and it may be that the bodies are wholly the result of a granitising wave of mineralisation. It is possible, however, that the bodies which are all aptly situated with regard to north-east faults are due to late phase leaching and concentration of ore. The importance recently attributed to the north-east folds by Conolly (see Alexander, 1953) suggests that this is so. The brecciation of the Owen Conglomerate at Comstock and North Lyell indicates late movement and there has been much cherty re-silicification of the breccias. At the Blow and at other localities the presence of barytes is suggestive of late activity and the presence of many varied and rare sulphides tends to support the idea. As far as the north-east faults are concerned there is a slight difference of nomenclature between the Mt. Lyell geologists, who call them flexures, and the writer, who calls them faults. This difference is not significant.

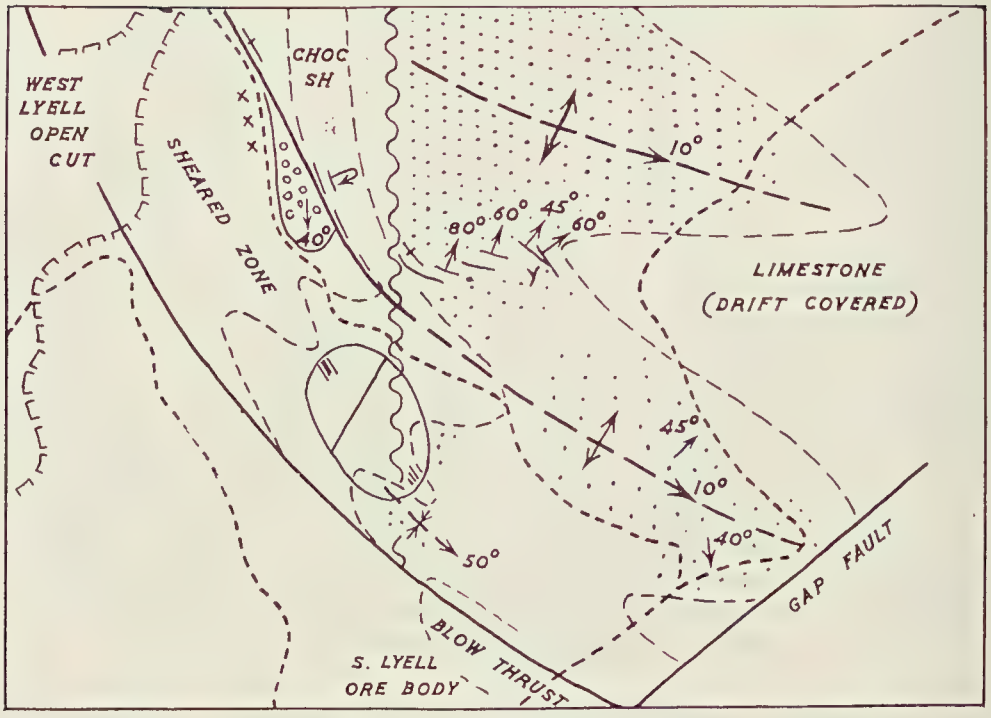

FIG. 17.—To illustrate the geology at the Blow Open Cut. Undulating line—boundary between schists (left) and non-schists (right); shortest dashes—roads; heaviest dashes—fold axes; heavy lines—faults; medium dashes—projected formation boundaries x denotes locality of sandstone dykes and y the position of a minor unconformity.

With these ideas in mind, and figures 9, 11 and 12 before us, the richer bodies may be examined, taking the Blow deposit as a type. This ore formation, which is now completely excavated, once formed a pipe-like body tapering downwards and the pipe, in the writer's opinion, can be seen to lie in the trough of a steeply plunging syncline which is divided by a smaller anticline. The ore was predominantly of chalcopyrite and pyrite with some bornite and was a replacement of the Chocolate Shales. Immediately to the south-west of the pipe the Blow thrust plane passes close by and provides a possible feeding channel, and on the north side of the body another shear occurs. A slight difference in the interpretation of the structure at the Blow is given by the writer as compared with Conolly (see Alexander, 1953) who carries the Blow thrust plane with a sharp twist through the Blow deposit. Here it is thought that there are two faults, the first being the Blow or Owen Spur thrust plane, and the second being a shear which begins only alongside the Blow (fig. 17). The Blow lies on the southern side and partly on the flank of a minor north-west fold, and as this fold is upturned at the Lyell Shear it breaks along its crest line and the southern limb is thrust over the northern. At the same time, intense alteration occurs along the break, and so we have the vertical limb in a very altered

condition. The progressive overturning of this northern limb is beautifully displayed along the old haulage line near the Blow and the more nearly horizontal southern limb is seen in the smaller Razor Back mass. It is just possible that this fault, as well as the Blow thrust plane, has been a feeder, but there are two more faults, both tensional north-east faults, which might serve in that role. The smaller of these can be seen in the south-west and north-east faces of the Open Cut. The latter exposure is poor but the former is clear, and it shows a clean cut fault plane with marked contortion to either side and with intense sericitisation along its length. The large fault is the Gap Fault, a fault which has not been proved in this immediate vicinity but which has been deduced as crossing Linda Valley. There are so many conflicting foci of alteration at the Gap that it is unlikely that the Gap Fault can ever be demonstrated except indirectly. The evidence for it is good—it can be observed on Mt. Lyell and on aerial photographs of that mountain—it has been drawn between the tilted ends of Linda Valley and there is evidence that it downthrows to the east. The latter consists of an exposure of a fine white loose sanlstone in the old railway cuttings south of Linda. This sandstone closely resembles, and is taken to be, the Crotty Quartzite—it is most unlikely that it has been confused with the Tubicolar Sandstone which in this vicinity is much different. If the folds at the western end of the valley are projected along their axial line they could hardly result in the exposure of the quartzite, and it is assumed that a fault has downthrown this formation to the east.

Figure 17 shows how the Gap Fault might serve as a feeder to the Blow deposit, i.e., by canalising along the syncline itself or along the Blow thrust plane. It is probable that there is no one answer to the problem of feeding channels, and it would be very difficult to choose between the north-east fault in the Blow or the Gap Fault, but there is perhaps some significance in the fact that the South Lyell body lay in depth (600 ft.) some 600 to 800 ft. to the south-west of the Blow (Alexander, 1953). Within the limits of the size of the body it seems probable that the ore lay at the intersection of the Blow and Gap Faults, and would, of course, coincide with the projection of the Chocolate Shales of the Blow Syncline, as shown in figure 9.

So far, as the details of other ore bodies are concerned the reader is recommended to Conolly's (1947) and Alexander's (1953) accounts but for the general reader the following general structural notes are made:—

The Comstock Ore Bodies.

The pyritic ore is located as irregular lenses in the monoclinal axis of the deflected North Lyell fold. The fold is readily traced in the bedded porphyries to the north and west of the mine and the porphyries appear underground with ore showing at the contact with the Owen Conglomerate. The steep monoclinal limb appears to have controlled the location of ore, but perhaps just as important is a north-east fault which the writer has inserted on figure 11. There is little direct evidence for this fault except in the presence of pronounced north-east joints and faces in the mine open cut. There must have been some late movement nearby for

the rocks around are highly brecciated and re-cemented by cherty silica and the writer would attribute these phenomena to a north-east fault. The ores near the surface are accompanied by much sericite and replace the Chocolate Shales and these replacements are similar to those at the Blow and North Lyell. A particular interest of the Comstock locality lies in the presence of a galena vein which occurs to the north-east of the open cut and which presumably lies on the north-east tension fault. As the vein is stratigraphically higher than the pyrite ores this provides another example of the zoning previously mentioned. Tensional faults seem to be a more natural home for lead ores than are shears but Broken Hill provides an excellent example to the contrary and so do the deposits at Tullah. It should have been mentioned earlier that the latter provide an example of frontal lead deposits and here at Comstock is an example of a tele-frontal deposit. It is of interest that slugs of galena have been found in the limestone near Linda and these are regarded as having an origin similar to the vein at Comstock and as having been deposited along the Gap Fault.

The North Lyell Mine.

This is the remaining rich ore body of the Lyell vicinity. It is again an irregular pipe lying in Chocolate Shales under an overhang of Tubicolar Sandstone. The ore is chalcopyrite with bornite and it lies close to the North Lyell Fault. There is little doubt that this fault has influenced deposition but according to Conolly north-east faulting has been equally if not more important.

West Lyell and Tharsis Mines.

The position of these bodies is indicated on figure 11 along with the trace of the relevant north-east faults, and taken together these tell their own story.

Conclusion

In environments like the West Coast Range it is not enough to make a separate study of rocks to arrive at their genesis or of ores to trace their origins. It is not enough to study sediments to guess at their environment of deposition nor to study structure as geometry. All of these must be studied as one, for they are like the parts of an organism, they have a common evolution and a fundamental unity.

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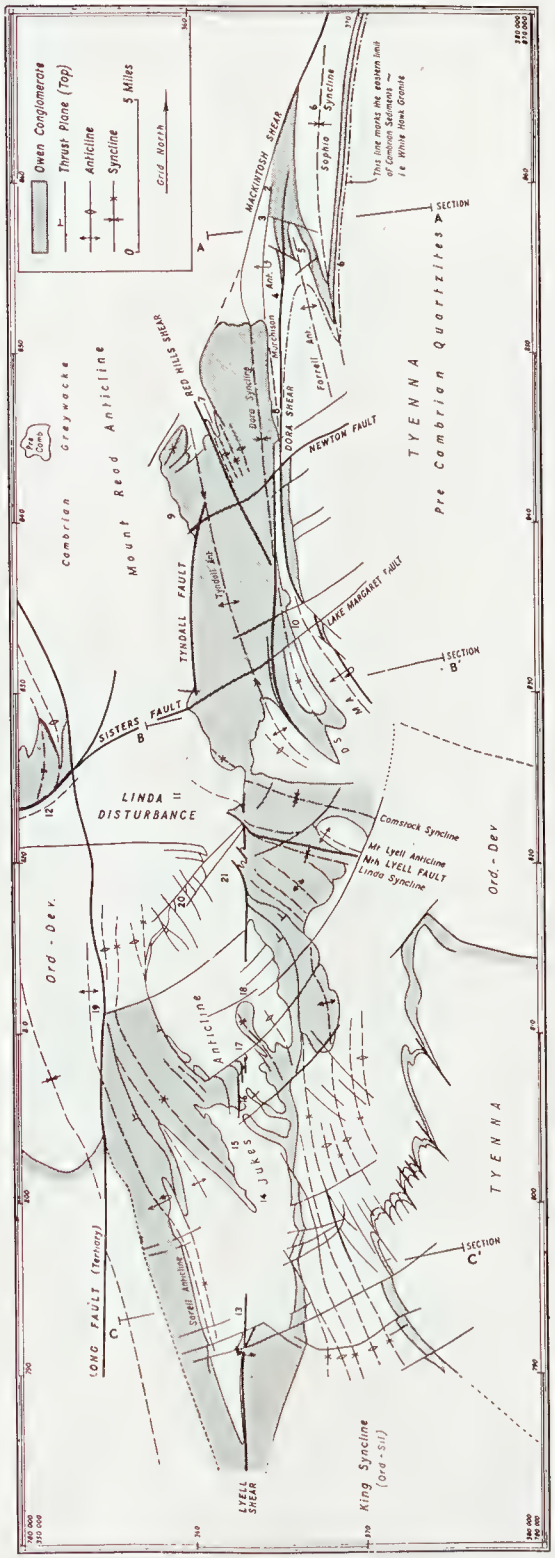


Macintosh R.

Sophia R.
Mt. Farrell

Mt. Murchison
Stitcht Range
Lake Julia
Anthony Creek

Mt. Tyndall

Lake Dora

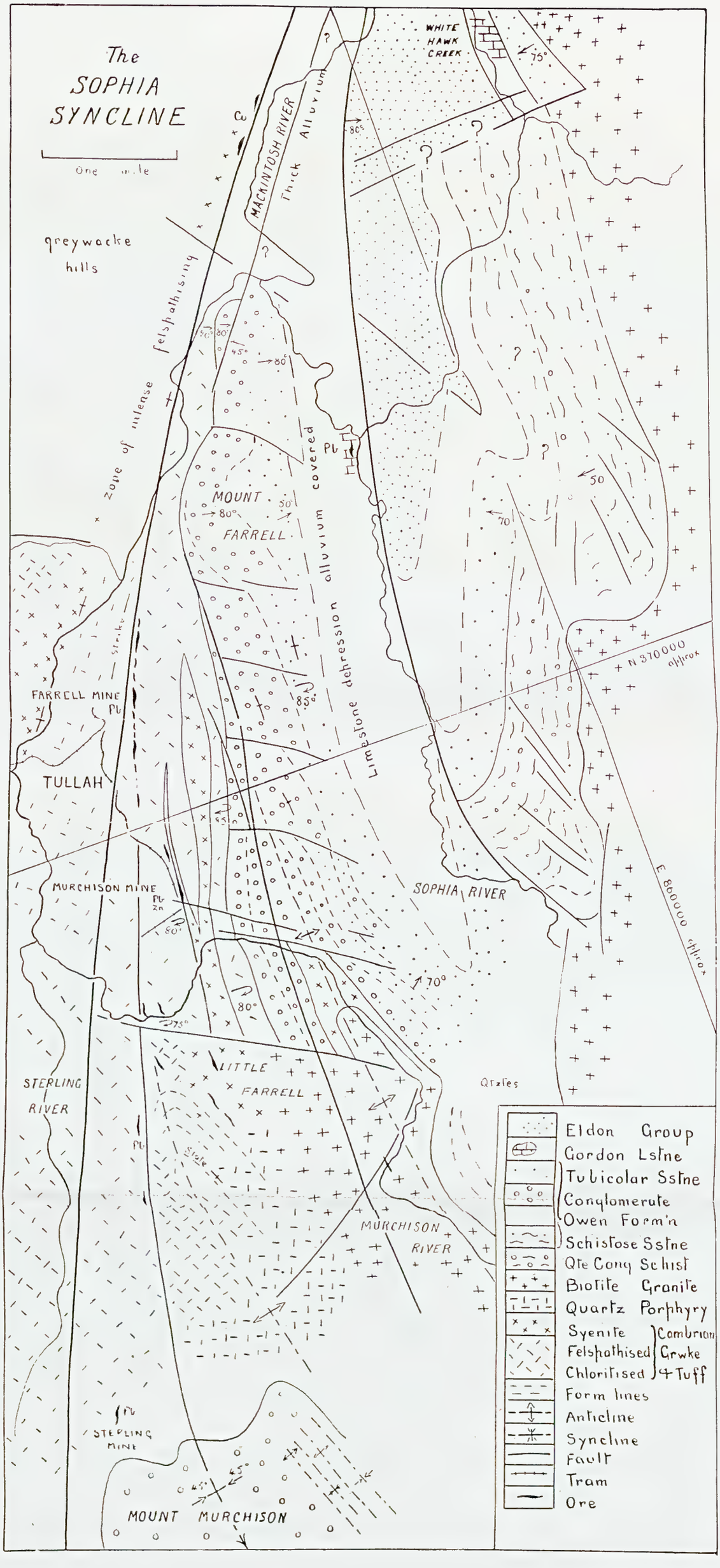
Mt. Sedgwick

Mt. Lyell
Mt. Owen

Mt. Huxley
Mt. Jukes

Mt. Darwin

Mt. Sorell
South Darwin Pk.


The
SOPHIA
SYNCLINE
One mile
greywacke
hills
MACKINTOSH RIVER
Thick Alluvium
WHITE HAWK CREEK
zone of intense felspathising
MOUNT FARRELL
alluvium covered
Limestone depression
FARRELL MINE
Pb
TULLAH
MURCHISON MINE
Pb Zn
SOPHIA RIVER
N 370000 approx
E 860000 approx
STERLING RIVER
LITTLE FARRELL
Strike
MURCHISON RIVER
STEPLING MINE
MOUNT MURCHISON
Qtzites
Eldon Group
Gordon Lstne
Tubicolar Sstne
Conglomerate
Owen Form'n
Schistose Sstne
Qte Conq Schist
Biotite Granite
Quartz Porphyry
Syenite
Felspathised
Chloritised
Cambrian Grwke & Tuff
Form lines
Anticline
Syncline
Fault
Tram
Ore

CYCLIC SEDIMENTATION IN THE PERMIAN SYSTEM OF TASMANIA

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(With Two Text Figures)

Communicated by Professor S. Warren Carey

Abstract

Detailed stratigraphic sections of the Berriedale Limestone were measured in five quarries in the Derwent Valley. In these are thin beds of volcanic ash which is now altered to montmorillonite clay. These clay beds provide a means of precise correlation within the Berriedale. A study of the insoluble residues of the limestone beds indicates rhythmic and cyclic deposition and suggests deposition in relatively deep water. Glacial erratics seem to be concentrated in or near the clastic layers. The Berriedale cycles are probably Leonard in age.

Cyclic sedimentation of another type occurs in the lower Woodbridge Formation near Clifton Beach.

Introduction

During the winter of 1953 the writer measured in detail a number of stratigraphic sections of Permian strata. Five of these sections are of the Berriedale Limestone which is well exposed in quarries in the Derwent Valley north-west of Hobart. One is a section of the basal Woodbridge formation north of Clifton Beach. These exceptional exposures provide detailed information that can be obtained at few localities in the State. This paper is an interpretation of the sedimentary cycles that occur in these strata.

The writer wishes to thank the staff of the Geology Department of the University of Tasmania for the many courtesies shown to him during his stay. Special thanks are due to Mr. M. R. Banks of the Geology Department and to Mr. G. E. Hale of the Tasmanian Museum who shared freely their knowledge of the Permian and who guided the writer in the field on many occasions. Some of the insoluble residue studies were made at the Museum under the direction of Mr. Hale. The writer wishes to thank Dr. Harold Wanless and Mr. F. W. Booker, who were kind enough to read the manuscript.

Berriedale Limestone

Cyclic sediments: The Berriedale Limestone which was named for exposures near the village of Berriedale (Lewis, 1946), is widespread in eastern Tasmania (Banks in Hill, 1955). Typically it consists of beds of marine limestone interbedded with mudstone. Glacial erratics are scattered through the formation. It becomes less limy toward the south and south-east, where it interfingers with the Grange mudstone (Banks in Hill, 1955).

This paper deals primarily with the exposures in quarries in the Derwent Valley; however, excellent exposures occur on Maria Island and in the vicinity of St. Marys. At these two localities the lithology of the Berriedale is much like that in the Derwent Valley, but the writer was unable to make a bed for bed correlation.

No detailed section of the type Berriedale Limestone has been published; therefore a section is appended to this paper. This section was measured by the writer in Weily Quarry near Glenorchy. Although this is not the type locality of the Berriedale, it is only about three miles from the type and is a longer and better exposure.

Columnar sections of the Berriedale Limestone shown in Fig. 1 do not represent the total thickness of the formation, but illustrate only those portions well enough exposed to allow a detailed study to be made. Sections were measured in the following quarry faces:

1. Weily Quarry, at reservoir, about 2 miles south west of Glenorchy.
2. Abandoned quarry on Old Collinsvale Road, about 3 miles west of Berriedale.
3. Abandoned quarry about 1·5 miles airline west of Granton.
4. Rathbones Quarry about 3 miles west of Granton.
5. Abandoned quarry on east flank of Mt. Dromedary near station of Bundella.

In each columnar section it may be seen that (*a*) beds of impure limestone alternate with calcareous mudstone, (*b*) beds of limestone tend to be thicker than beds of mudstone, (*c*) limestone is more resistant to weathering. The repetition of such bedding indicates cyclic sedimentation.

In all sections the writer found thin beds of devitrified volcanic ash which has been altered to montmorillonite. These beds are associated with the mudstone layers. At least 13 beds of altered ash have been found in the Glenorchy section. Some of them can be traced through several sections. The most persistent bed is about an inch thick and is here referred to as the Lower Marker bed. Some 15 feet above this is another persistent layer called the Upper Marker bed. By means of these two markers, bed for bed correlation between sections is possible (Fig. 1). Although some beds of volcanic ash may be present in the Berriedale Limestone on Maria Island, it is not possible at the present time to correlate them with any of the beds in the Derwent Valley. No evidence of ash beds was found in the detailed section near St. Marys.

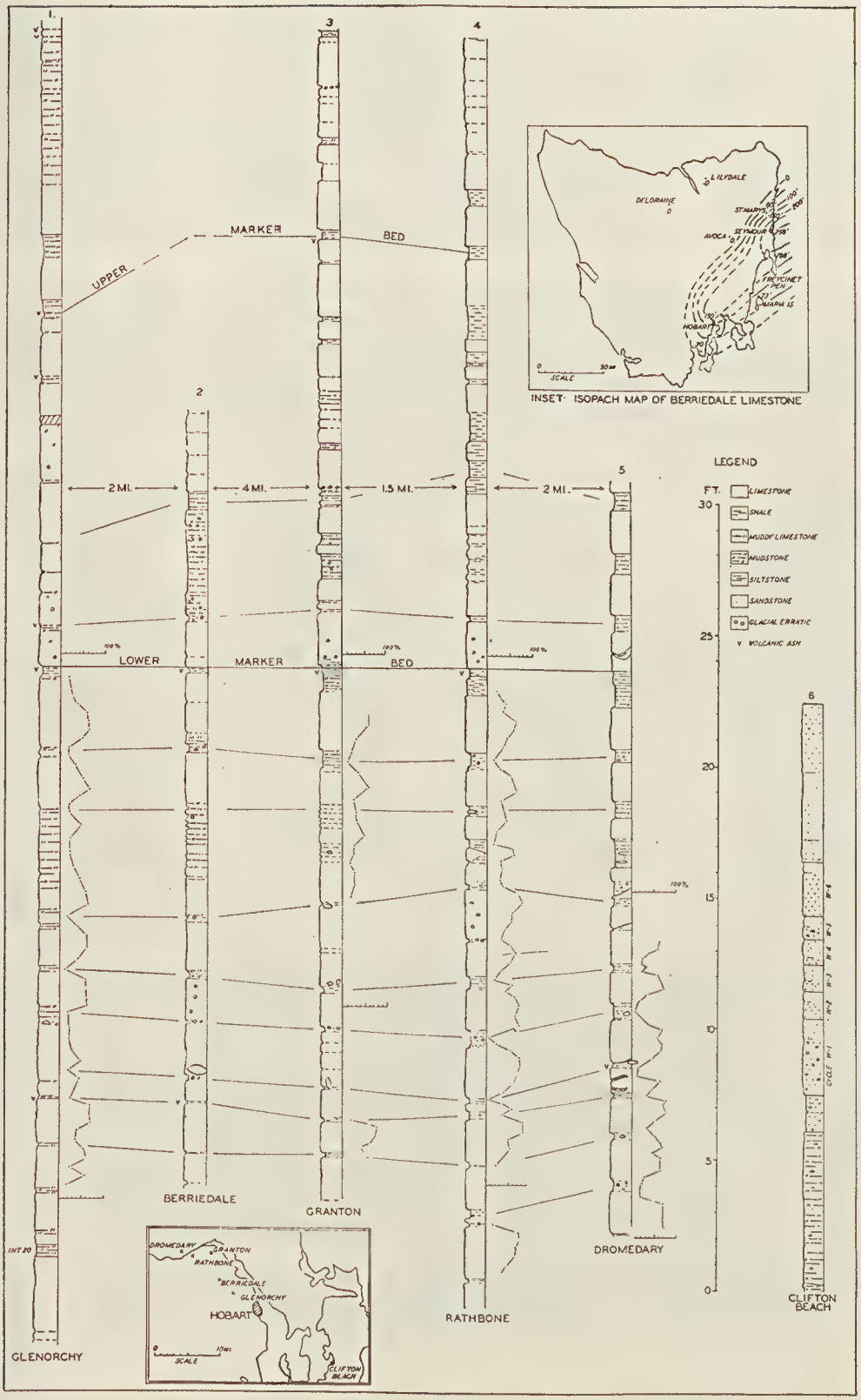

FIG. 1.—Columnar sections of Permian strata. Sections 1-5, parts of the Berriedale Limestone. Section 6, part of the lower Woodbridge Formation. The percentage of solubles is shown in the graph at the right of the section.

Pebbles and boulders composed of quartz, igneous and metamorphic rocks are scattered throughout the Berriedale. The largest observed is a granite boulder more than a foot in diameter in the quarry west of Berriedale. Figure 1 shows that the fragments tend to be more numerous in or near the mudstone layers. Concentrations of erratics occur in several cycles below the Lower Marker bed, namely, the top of cycle 4, the top of cycle 5, the top of cycle 6 and the base of cycle 6. It is assumed that these fragments are glacial erratics that have been rafted to their present position by icebergs; however, only one erratic out of several hundred examined by the writer showed striations.

In Fig. 1 solubility graphs are shown on the right side of several of the columnar sections. Series of chip samples provided data for these graphs. Samples of about 20 grams each were taken at about 4-inch intervals up the quarry face. Each sample was weighed dry, digested in acid, and the insoluble residue weighed dry. The per cent soluble matter thus obtained for each sample is plotted on the right side

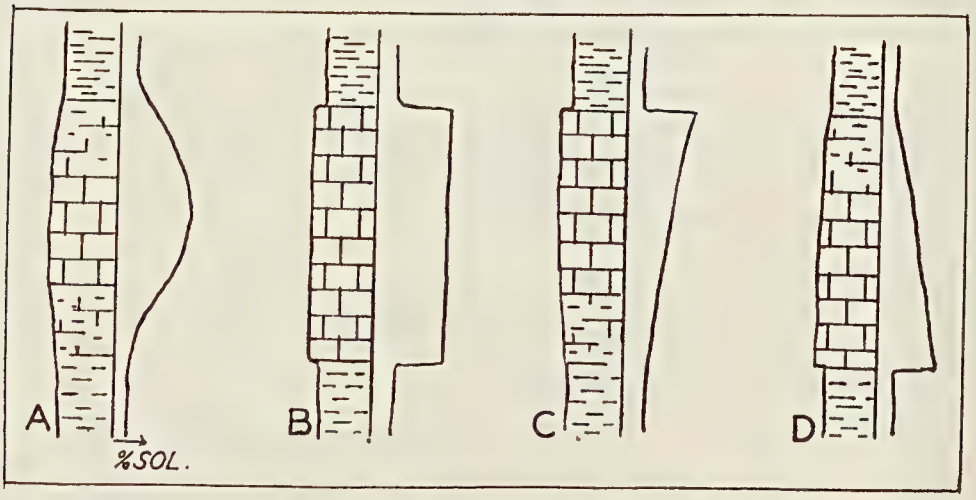

FIG. 2.—Four types of solubility curves in limestone beds.

A. Gradational contacts with beds above and below, typical of Berriedale Limestone, suggesting: relatively deep or quiet water below wave base, uniform cyclic fluctuation of sea level or supply of sediment.

B. Non-gradational contacts with beds above and below, typical of Warsaw formation (Lower Carboniferous) in St. Louis County, Missouri, suggesting: control by diastems, rapid vertical fluctuations of wave base, cycles interupted.

C. Gradational contact below, non-gradational above, a hypothetical case suggesting: a gradual increase in depth of water, decrease in clastic sediment, or chemical precipitation of limestone due to bacterial activity in underlying shale (Shrock, 1948, p. 31).

D. Gradational contact above, non-gradational below, a hypothetical case suggesting: gradual decrease in depth of water, increase in supply of clastic sediment.

of the columnar section. Although samples were not taken from all parts of each section, the solubility curve shows a repetitive pattern in each section and the gross features of it can be traced from one section to another. The typical cycle shows a maximum of mudstone deposition followed by a gradual decrease in clastic material until a maximum of limestone deposition is reached. This is followed by a gradual increase in mudstone deposition to the beginning of the next cycle. The greatest purity of the limestone beds occurs at or slightly above the middle in most beds. The graph seems to indicate that sedimentation is both cyclic and rhythmic (Moore, 1950, p. 6).

Four types of solubility curves that are possible for a limestone bed are shown in Fig. 2. Each curve suggests a different set of conditions under which the bed was deposited. The solubility curve that is characteristic of the Berriedale Limestone shows a gradual increase in insolubles at the top and bottom of the bed (Fig. 2A). This condition indicates continuous deposition with variation in the volume of clastic sediment. The lack of rapid changes in lithology between beds suggests deposition in relatively deep water unaffected by violent wave action. Angularity and freshness of mineral grains in the Permian was interpreted by Banks (1952, p. 72) as evidence of quiet water deposition. The presence of large numbers of productid brachiopods, pectenoid pelecypods and bryozoa in the Berriedale does not militate against the theory of moderately deep water. Barrell (1916, p. 803) states that marine mudstone seems to give the most favourable conditions for continuous record, and is well adapted especially where alternating with lime or silt beds to give a basis for the analysis of rhythms. In this respect the Berriedale Limestone seems to be an ideal formation for studying rhythms; however, the problem is complicated by three different types of sedimentation—glacial and sedimentary cycles and volcanic ash deposits.

The cause of rhythmic and cyclic sedimentation in the Berriedale is obscure. If it is due to eustatic changes in sea level, the problem is not unlike that of cyclothems in many parts of the world. The fact that thin beds of volcanic ash are associated with the mudstone beds and that commonly glacial erratics occur in or close to the mudstone beds suggests that all three may be related genetically.

Several hypotheses suggest themselves: (*a*) Volcanic outbursts in areas of glaciation may have increased glacial melting and thereby increased clastic deposition. (*b*) Volcanism may have increased precipitation on land and thereby increased discharge of streams and glacial flow. (*c*) The vertical movements of the sea floor may have resulted from earth movements associated with volcanism, in which case the presence of glacial deposits may have been entirely fortuitous. (*d*) Changes in the rate of sedimentation may reflect the waxing and waning of glaciers, in which case the presence of volcanic deposits may have been fortuitous.

Lithofacies. The isopach map (Inset, Fig. 1) indicates that the Berriedale Limestone thickens toward the north-east. Southward and south-eastward it interfingers with calcareous mudstone. The greatest thickness of limestone seems to be in the No. 4 Bore at Seymour (Voisey,

1938). Some of the generalizations on this map are borne out by more detailed information from the Berriedale in the Derwent Valley.

Detailed lithologic data are available for only a part of the Berriedale at all five localities. Table 1 shows the total thickness of each type of rock in each section for the 8 cycles below the Lower Marker bed.

TABLE 1

Section	Sandstone	Siltstone	Mudstone	Shale	Limestone
Glenorchy	....	....	1′ 9″	8″	17′ 6″
Berriedale	....	....	1′ 9″	4½″	17′ 4″
Granton	....	4″	1′ 3″	1′ 8″	17′ 1″
Rathbone	2″	5″	2″	3′ 2″	14′ 10″
Dromedary	....	6″	4′ 11″	1″	14′

These thicknesses indicate that the amount of clastic material increases toward the west. A greater number of beds bearing glacial erratics occur in the Dromedary and Granton sections, suggesting that the source of pebbles may have been to the west or north-west. More beds of volcanic ash occur in the Glenorchy section which may be significant as to source direction, or may indicate only deeper water. In the Glenorchy, Granton and Rathbone columnar sections lithologic data are available for the strata between the Lower Marker and Upper Marker beds. These also indicate that the amount of clastic sediment increases toward the west. Although comparative figures on lithofacies are available for only a portion of the Berriedale Limestone, they appear to be significant and consistent for this geographical area.

Age: The waxing and waning of ice sheets in the Southern Hemisphere has been suggested by Wanless and Shepard (1936, p. 1193) as a possible cause of cyclothems in Upper Carboniferous and Lower Permian strata in the United States. Moore (1950, p. 16), on the other hand, cites evidence to the contrary.

Although the Berriedale cycles may be related to fluctuations of glaciers, it is doubtful that they can be correlated with any known sedimentary cycles in the United States. Faunal studies of the Berriedale by Banks (1955) indicate that it contains *Lyroporella*, *Streblotrypa* and *Fenestella chapmani* which are also found in the Callytharra Limestone of the Carnarvon Basin in Western Australia. The Berriedale also contains *Taeniothaerus subquadratus* and *Neospirifer* cf. *moosakhailensis* which occur in the Wandagee Formation of the same area in Western Australia. According to Teichert (1949, p. 35) the Callytharra Limestone is very early Artinskian in age. Teichert (1942, p. 222) states that the Wandagee, although stratigraphically higher than the Callytharra, is also Artinskian. If these correlations are correct the Berriedale Limestone is approximately Leonard in age, and, therefore, younger than any of the well-known coal cyclothems in the United States.

Woodbridge Formation

The Woodbridge Glacial Formation (Voisey, 1938) is younger than the Berriedale Limestone. Typically it consists of sparingly fossiliferous mudstone and sandstone with numerous glacial erratics. It thins toward

the north-east, being about 200 feet thick in the Derwent Valley, about 55 feet thick on Freycinet Peninsula, about 25 feet thick in the No. 4 Bore at Seymour (Voisey, 1938), and 3 feet thick at Elephant Pass near St. Marys. In the three localities last mentioned it is glauconitic.

At least six sedimentary cycles occur in the basal Woodbridge Formation at the north end of Clifton Beach near Cape Deslac (Fig. 1). The lowest cycle begins in the cliff 104 feet above sea-level. The section above the sixth cycle is not exposed. Each cycle consists of two members. In the lowest cycle the lower member is a conglomerate of angular and subangular fragments of mudstone, porphyry and quartzite up to 8 inches in diameter. The lower members of the other cycles consist of coarse-grained quartz sandstone. The upper members of all cycles are finer-grained sandstone. In four of the six cycles the upper member is thinner than the lower. The lower member of one cycle contains a few fossils indicating that these sediments are marine.

These cycles may be a modification of the deltaic cyclothems of Wanless and Shepard (1936), and may have developed on a mildly unstable shelf near a source of glacial outwash. The members of the Woodbridge cycles are much thinner than any of those illustrated by Wanless and Shepard.

Good exposures of this particular part of the Woodbridge were not seen elsewhere in this area, therefore the areal extent of these cyclothems is not known. They do not seem to be present in the section along the New Norfolk road west of Rathbone quarry.

Sedimentary cycles have been recognized in the Tomago Coal Measures in New South Wales (Booker, et al, 1954, p. 147). It is doubtful that the Woodbridge cycles are related in age to those of the Tomago; however, they may be related genetically.

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Appendix

Detailed section of a part of the Berriedale Limestone in Weily's Quarry about 3 miles south of Glenorchy.

		Ft.	In.
Top of section:			
Grange Mudstone—			
65.	Mudstone weathers grayish-white, beds one foot to 18 inches thick, exposed in top of quarry	15	0
Berriedale Limestone—			
64.	Shale dusky yellow, very silty, laminated, perhaps metabentonite	0	0¼
63.	Mudstone weathers grayish-white, discontinuous shale band in middle of interval, a thin green shale band 8 inches above base; pectens, fenestellids	0	10
62.	Shale dusky yellow, laminated, waxy feel, metabentonite	0	4
61.	Mudstone gray, perhaps slightly limy, beds about 1 foot thick, prominent bedding plane 1 foot below top	4	6
60.	Limestone medium dark gray, massive, rounded fragment of schist 8 inches diameter near base, *Strophalosia*	3	1
59.	Mudstone olive gray, massive, numerous fenestellids give impression of laminae	0	8
58.	Shale dusky yellow, silty, perhaps metabentonite	0	0¼
57.	Limestone medium dark gray, muddy streaks, broken into thirds by two bedding planes; globular *Strophalosia* or *Taeniothaerus* in middle of interval	2	6
56.	Shale dusky yellow, silty, perhaps metabentonite	0	0¼
55.	Mudstone olive gray, slightly calcareous	0	9
54.	Shale dusky yellow, waxy feel, metabentonite	0	1
53.	Mudstone olive gray, slightly calcareous, one bed, laminae due to fenestellids	2	8
52.	Shale dusky yellow, soft	0	0¼
51.	Limestone medium dark gray, slightly muddy streaks, discontinuous shale (metabentonite?) 4 inches above base; *Strophalosia*, large *Stenopora*	1	8
50.	Shale dusky yellow, thin-bedded, soft, probably metabentonite	0	0¼
49.	Mudstone olive gray, calcareous streaks due to many fenestellids, silty, poorly bedded, bedding planes at 12, 23, 44, 56 inches above base	5	7
48.	Limestone medium dark gray, many muddy streaks and lenses, laminations due to fenestellids	2	0
47.	Mudstone olive gray, calcareous streaks, laminations due to fenestellids	0	10
	Overlying layers generally muddier than those below.		
46.	Limestone medium dark gray, slightly muddy, massive	1	8
45.	Mudstone olive gray, non-calcareous, laminations due to fenestellids	0	4
44.	Shale dusky yellow, waxy feel, thinly laminated, metabentonite. Upper marker bed	0	4
43.	Limestone medium gray, slightly muddy, upper 6 inches muddier, massive, prominent bedding plane 19 inches above base. Floor of upper bench	2	1
42.	Shale dusky yellow and dark greenish-gray, waxy feel, metabentonite	0	1
41.	Limestone medium dark gray, muddy near top, massive, small encrusting bryozoa	1	5
40.	Dolomite medium dark gray, muddy, laminae due to fenestellids	0	5
39.	Limestone medium dark gray, muddy and sandy streaks, scattered small pebbles, small black muddy nodules, containing bryozoa; many *Stenopora*, fenestellids, few spiriferids	2	1
38.	Mudstone dark gray, discontinuous bed	0	1
37.	Limestone medium dark gray, fetid odor, massive, but thin breaks of limy mudstone 11, 20, 33 inches above base; fenestellids, a few brachiopods	4	3

		Ft.	In.
36.	Limestone medium dark gray, slightly muddy, fetid odor, scattered rounded pebbles up to 2 inches diameter, many *Stenopora*	1	4
35.	Shale and mudstone interbedded; shale dusky yellow, perhaps metabentonite; mudstone gray	0	1
34.	Limestone medium dark gray, massive, slightly muddy, top 2 inches muddier, scattered small dark rounded pebbles; large *Stenopora* near middle of the bed	1	6
33.	Shale dusky yellow, thin-bedded, waxy feel, top silty, base without bedding, metabentonite. Lower marker bed	0	5
32.	Limestone medium gray, massive, scattered spiriferids and *Strophalosias* mainly smaller than in sections to the north; upper 2 inches muddier with abundant fenestellids	2	9
31.	Limestone dark gray with mudstone breaks, fenestellids, *Trigonotreta*, *Stenopora*	0	4
30.	Limestone medium dark gray, nearly a coquina at top of small *Strophalosia* and other small shell fragments	2	0
29.	Limestone medium dark gray, many thin muddy breaks; about one-third calcareous mudstone on fresh surface	2	5
28.	Limestone medium dark gray, muddy, one bed	1	11
27.	Limestone similar to Int. 25; thin muddy breaks in upper 3 inches	1	7
26.	Mudstone dark gray, thin-bedded, calcareous	0	3
25.	Limestone medium dark gray, slightly muddy, muddy breaks 3, 5 inches above base; numerous brachiopods	1	9
24.	Limestone medium dark gray, slightly muddy, massive; a 1-inch soft muddy streak 7 inches above base; coarse angular quartz and rock grains; subangular fragments of quartzite 5 inches diameter at top. Seems to be a thin metabentonite here	3	0
23.	Shale dusky yellow, waxy feel, thin-bedded, mixed with limestone, metabentonite	0	1
22.	Limestone medium dark gray, finely crystalline, 2-inch darker, more shaley band at base and 21 inches above; many spiriferids, *Eurydesma*, *Strophalosia*, composed of white calcite	3	7
21.	Limestone medium dark gray, muddy, fetid odor, 2-inch muddier band 5 inches above base; many fossils. Forms floor of 3rd bench in quarry, Cross small fault	2	0
20.	Mudstone dark gray, very limy, weathers brown at top; many *Strophalosia*	0	5
19.	Limestone dark grey, massive, fossiliferous beds with thin shale breaks at 21, 29, 36, 40, 43, 49, 53 inches above base. Large *Stenopora*, but spiriferids, *Strophalosia* smaller than farther north	7	4
18.	Mudstone dark gray, thin poor bedding, calcareous streaks; fenestellids, *Strophalosia*	0	4
17.	Limestone dark gray, many dark muddy streaks, many angular to rounded pebbles of quartzite, limestone and metamorphic rocks up to 4 inches diameter; many *Strophalosia* and spiriferids	2	9
16.	Limestone dark gray, very muddy, fetid odor, scattered *Stenopora*, *Strophalosia;* prominent bedding plane at top and bottom	0	5
15.	Limestone medium dark gray, dark muddy areas with brachiopods, fetid odor, scattered pebbles up to 2 inches diameter	1	8
14.	Limestone medium dark gray, thin bands and lenses of dark carbonaceous shale; bedding planes at 27, 46, 50 inches above base; many spiriferids, *Strophalosia* composed of white calcite, weathers cavernous, relatively pure bed. Floor of 2nd bench in quarry	4	6
13.	Shale and limestone; shale dusky yellow in two thin beds at top and bottom; limestone dark gray, muddy 1½ to 2 inches thick	0	3
12.	Limestone medium dark gray, weathers light gray, muddy, massive, prominent bedding planes at base and 32, 37, 42 inches above base, scattered subangular fragments of quartzite, dark metamorphic rocks up to 3 inches diameter	6	0

		Ft.	In.
11.	Limestone medium gray, massive, irregular muddy lenses a few mm. thick, streaks of sandstone, prominent bedding planes at base and 23, 49, 59 inches above base, subangular pebbles of quartzite and black argillite up to 1 inch in diameter especially in upper 1 inch	6	5
10.	Mudstone olive gray, silty, many fenestellids. Floor of quarry	0	2
9.	Shale dusky yellow, thin bedded, some may be slightly waxy, mainly silty, hard; weathers white like metabentonite	0	2
8.	Mudstone and limestone interbedded; mudstone olive gray, calcareous, silty, many fenestellids. Basal 1 inch contains flakes of metabentonite. Top of bed is three feet below access road	9	0
7.	Mudstone olive gray, hard, spiriferids and many fenestellids	2	0
6.	Mudstone olive gray, scattered angular quartz fragments, small clams and ostracodes	1	0
5.	Mudstone olive gray, silty, many fenestellids	1	8
4.	Shale dusky yellow, hard, silty	0	3
3.	Limestone olive gray, muddy, scattered sand grains, and lumps of gray mudstone	0	8
2.	Mudstone dark gray, weathers brown, slightly calcareous, numerous grains and pockets of quartz sand; pectens, spiriferids, small bryozoa, *Dielasma*	2	0
1.	Sandstone medium gray, muddy with limy spots, subangular pebbles up to 2 inches diameter; basal 1 foot partly covered	4	0
	Covered by dump.		

A NEW SPECIES OF *REGATARMA* WOODWARD FROM TASMANIA

(Hemiptera: Lygaeidae: Rhyparochrominae)

By

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(Communicated by L. E. Couchman)

(with one plate)

Abstract

The first Australian record of the genus *Regatarma* is noted and the new species *R. tasmaniensis* described and compared with the two New Zealand species. The affinities and distribution of these flightless bugs are discussed.

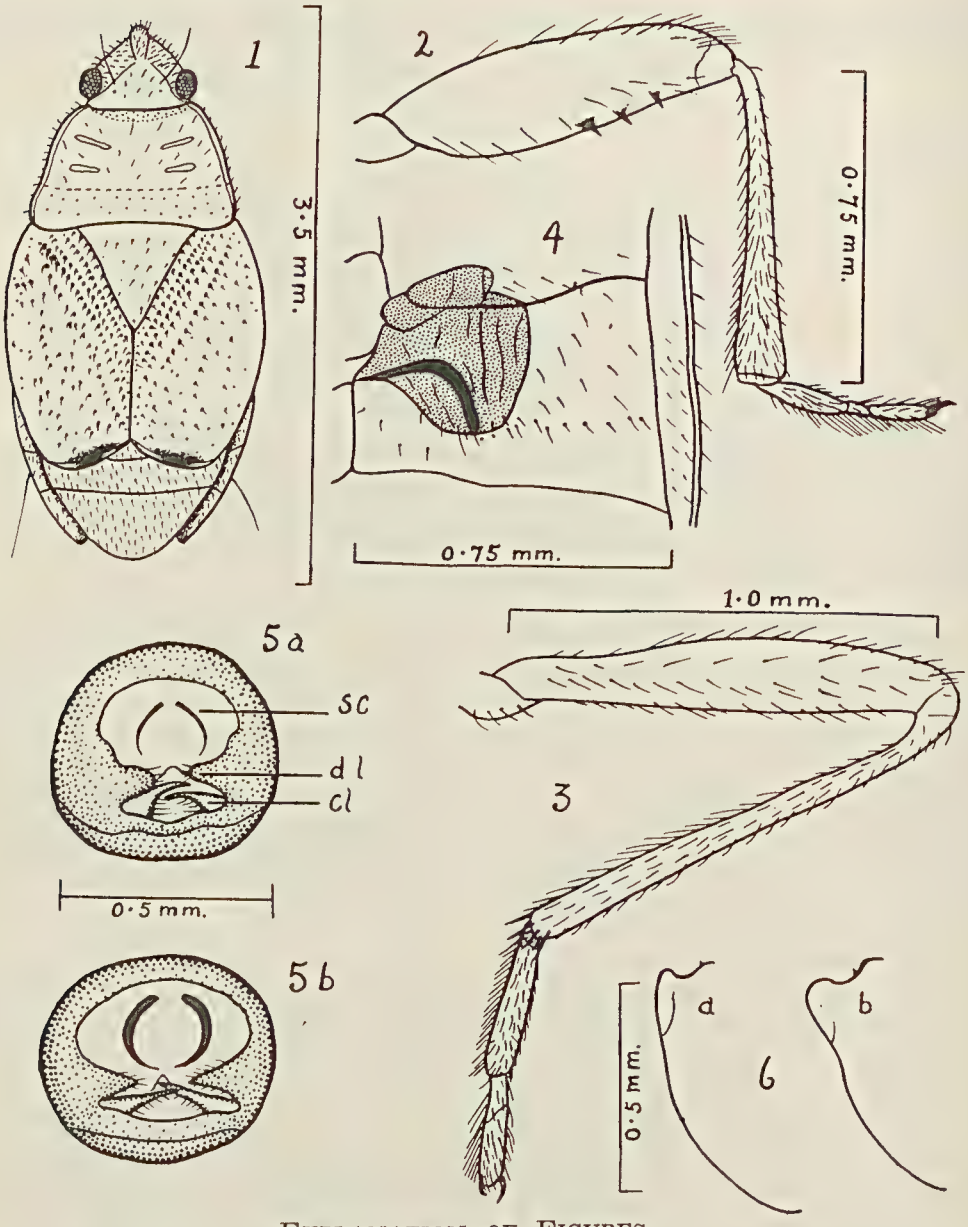
I am very much obliged to all those who gave me information and help on collecting areas in Tasmania and, with especial regard to the present work, in particular to Mr. and Mrs. L. E. Couchman, of Hobart.

The genus *Regatarma* was erected by the writer (1953: 196) to include two sub-brachypterous species occurring in leaf mould and in moss and lichens in New Zealand. The species are flightless, lacking hind wings, and are evidently specialised for life in the forest floor. One species, *R. salmoni,* is monotypic and has been found only near L. Wakatipu in the South Island. *R. forsteri,* on the other hand, extends through the southern and western parts of the South Island and the southern and central parts of the North Island; six subspecies have been distinguished. The three subspecies from the South Island are relatively archaic in having the membranes of the hemelytra better developed than in the northern subspecies and thus approaching more closely the ancestral macropterous condition.

A species of *Regatarma* is now recorded from Tasmania; no members of the genus have been found on the Australian mainland. This fact, together with the relative primitiveness of the more southerly New Zealand subspecies of *forsteri* and the absence of this species from North Auckland, is suggestive of a southern origin for the genus.

Tasmaniensis, moreover, resembles the South Island subspecies in having very broad membranes extending across the whole width of the hemelytra. Like the two subspecies occurring south of Westport, it is also larger than the four more northerly New Zealand forms. *R. salmoni,* though southern, is rather small and with very reduced membranes, but in other respects too this is a relatively highly specialised species.

Numerous other examples are known of groups of animals and plants common to Tasmania and New Zealand and apparently of a southern origin. But in view of the accepted absence of land connections since the Mesozoic and the limited powers of dispersal of these bugs, the occurrence of such closely related species in the two regions nevertheless seems remarkable.



Explanation of Figures

Fig. 1.—*Regatarma tasmaniensis* n. sp., ♂ dorsal.

Fig. 2.—*R. tasmaniensis*, ♂, fore leg, anterior aspect (the most basal femoral spine is often lacking).

Fig. 3.—*R. tasmaniensis*, ♂, hind leg, anterior aspect.

Fig. 4.—*R. tasmaniensis*, venter of left half of metathorax and of posterior part of mesothorax, to show evaporating areas (stippled) and spout of metathoracic orifice.

Fig. 5.—♂ pygophor, dorsal aspect. *cl* right clasper, *dl* dorso-lateral lobe, *sc* sclerotisation of dorsal membrane. *a R. tasmaniensis; b R. forsteri* Woodward.

Fig. 6.—*a* lateral view of posterior margin of pygophor of ♂, *R. tasmaniensis*. *b* the same of *R. forsteri*.

Regatarma can be placed in the tribe Lethaeini Stăl on the basis of its trichobothrial pattern. In the past some workers have merged the Lethaeini with the Rhyparochromini or other tribes and the status and limits of the former have yet to be determined accurately on a world basis.

The material described was collected and extracted by the author from moss and leaf mould by a portable funnel (design of Salmon, 1946).

In proportionate measurements, 75 units = 1 mm.

Regatarma Woodward, 1953

As with most Rhyparochrominae, the posterior margin of the third abdominal sternum is strongly curved forward at the sides and does not reach the lateral margins; there are two long erect hairs on the crown between the eyes.

The character referred to above as placing the genus in the tribe Lethaeini is: fourth abdominal sternum with three trichobothria on each side, the second remote from the posterior margin of the sternum and closer to the anterior trichobothrium. In all three known species of *Regatarma* the third trichobothrium is much closer to the second than to the posterior margin; the grey, finely granular second and third trichobothrial areas, from which the long sensory setae arise, are contiguous or very nearly so. In this latter feature *Regatarma* resembles *Metagerra* Buch. White, to which it is closely related.

Regatarma tasmaniensis n.sp.

Length.—3·4-3·8 mm. (♂); 4·0-4·25 mm. (♀). Greatest width across closed hemelytra.—1·5-1·6 mm. (♂); 1·8-1·9 mm. (♀). Ratio, length to width.—2·1-2·3. Ratio of basal width of pronotum to its median length.—1·7-1·9. Width of head across eyes.—0·73-0·81 mm. (♂); 0·81-0·83 mm. (♀).

Colour reddish brown. Hemelytra paler, more yellowish than body, with more or less distinct pale spots and streaks, including a longitudinal streak near base, an oblique streak at outer margin of claval area, and usually a subcostal patch before apex; apical margin of corium infuscated, the infuscation extending more or less on to the short membrane, which is otherwise pale. Pronotum with anterior margins and middle of basal margin narrowly infuscated; posterior lobe with a small yellowish streak in mid-line and on each lateral angle. Often a median dark line on anterior pronotal lobe and on scutellum. Antennae testaceous, II and sometimes I more or less infuscated, III and IV often fuscous. Rostrum and legs yellowish brown, the former and the coxae, trochanters, and femora except at apex, darkened. Meso- and metathoracic evaporating areas greyish; spout brown or brownish black. Venter of abdomen infuscated, shining.

Head.—Base of crown with a minutely granular triangular area, the apex directed forward to base of tylus; apex of tylus and sides of head, anterior to antennifers and including bucculae, shining, smooth; rest of head coarsely rugose-granular. Ocelli minute. Eye less than one-third as wide as interocular space (♂, 10: 35; ♀, 11: 40). Bucculae

reaching base of head, but posteriorly converging and becoming very low. Rostrum with segment I reaching base of head; II and III reaching about middle of fore and mid coxae respectively, IV reaching about posterior level of hind coxae; length, I: II: III: IV, as 36: 38: 28: 24 (♂), 41: 42: 33: 28 (♀). Length of antennal segments I: II: III: IV, as 28: 40: 31: 39 (♂), 33: 47: 37: 47 (♀).

Thorax.—Pronotum with anterior margin nearly straight, base broadly concave. Basal width: median length as 95 : 51 (♂), 112 : 60 (♀). Calli inconspicuous, foveae scarcely impressed. The transverse impression separating the anterior and posterior lobes very shallow, obsolescent; lateral margins only very shallowly sinuate between lobes. Punctures of posterior lobe minute, obsolete. *Scutellum* nearly flat, punctures fine and shallow; anterior width: median length :: 56 : 51 (♂), 65 : 65 (♀), 61: 65 (♀). Hairs of scutellum and hemelytra very short, inconspicuous, not obscuring the punctures. *Hemelytra* reaching but not (in specimens seen) completely covering the penultimate of the complete tergites (those with connexival paratergites), and leaving exposed also a triangular median sector of the next tergite in front. Punctures largest and deepest on claval region. Apical margins very broadly rounded, nearly straight, anteriorly converging in mid-line. Membranes extremely short but broad, extending across entire width of apex. Hind wings absent. *Thoracic venter.*—Metathoracic evaporating area nearly oblong, with two longitudinal grooves outside spout and several smaller, more or less oblique grooves and folds; orifice with spout narrowly crescentic; spout not broadened posteriorly, reaching or almost reaching posterior margin of evaporating area. *Legs.*—Front femora with a ventral row of two or three thorn-like spines on apical half (the number may differ on the opposite legs of the same bug). Ventral tubercles of front tibiae of male minute, none spine-like. Length of hind femur 0·9 basal width of pronotum. Hind leg with basitarsus ½-¾ as long again as last two subsegments together.

♂ *Terminalia.*—Dorso-lateral lobes of pygophor with apices broadly, not acutely rounded as seen in dorsal view and with anterior margins markedly concave. Sclerotisations of dorsal membrane of pygophor very narrow. (Fig. 5.) Posterior lip of pygophor (behind lobes), as seen in side view, narrower than in *forsteri* and posterior wall of pygophor beneath it scarcely concave (Fig. 6).

Types.—Holotype ♂, allotype ♀, paratype ♂, Mt. Wellington, Hobart (ex moss, rainforest, near O'Grady's Falls, 26. I. 1955); paratype ♂, same locality (29. I. 1955). Paratype ♂, 2 paratype ♀, near Russell Falls, Mt. Field Nat. Park (ex moss and leaf mould, rain forest, 29. I. 1955). Holotype and allotype deposited in Queensland Museum; paratypes in Australian Museum (Sydney), British Museum (N.H.), Entomology Department, University of Queensland, National Museum of Victoria and the South Australian Museum.

R. tasmaniensis shows very close affinities to the New Zealand species *forsteri,* especially to its southern subspecies. From *salmoni,* both the above species differ in the shape and grooving of the metathoracic evaporating area, the narrower and longer spout, the unridged claval

area, and the shallower foveae and transverse impression of the pronotum. In addition to the differences in male terminalia, noted above, the Tasmanian species may be distinguished from both *forsteri* and *salmoni* by the pronotum being less strongly sinuate at the sides, by the broader and less rounded apical margins of the hemelytra, and the obsolescent tubercles of the fore tibiae of the male. From *forsteri* it also differs in the wider pronotal base in proportion to median length. The ratio is similar in *tasmaniensis* and *salmoni,* but from different causes; in *salmoni* the pronotum is shortened whereas in *tasmaniensis* it is much more widened at the base relative to the anterior width than in either of the New Zealand species. From *salmoni, tasmaniensis* differs also in the much larger membrane, the larger size of the female, and the shorter hairs.

Since writing the above account I have received a further specimen which extends the known range of this species in Tasmania. It was extracted from leaf mould sent by Mr. F. E. Ellis, Director, Queen Victoria Museum, Launceston, and collected by Mr. N. Hoyle, of Perth, Tasmania. To both these gentlemen I wish to extend my thanks. Locality data and some measurements which slightly extend the previous size ranges: Waratah—Corinna (West Coast) (dense rain forest of " Myrtle " (*Nothofagus cunninghami*) and Sassafras, early December, 1955, 1 ♀); length, 3·87 mm.; width of head, 0·80 mm.; hemelytra entirely covering third complete tergite from end.

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THE GEOLOGY OF THE UPPER HUON–ARVE RIVER AREA

By

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(With Two Maps)

Abstract

Permian and Triassic rocks have been intruded in a complex manner by dolerite of lower Jurassic(?) age. The Permian rocks consist of mudstones, limestone and some sandstone with a total thickness of at least 870 feet. At least 800 feet of Triassic rocks are present, consisting of uniform fine grained quartzose-sandstone and micaceous shales. The structure of the area appears to be controlled by the dolerite intrusions.

Introduction

During January, February, 1955, the map squares 4769 and 4770 were mapped as part of a geological investigation of the Upper Huon and Arve River areas. The general structure and stratigraphy of the area were determined. The work was carried out using maps obtained from the Forestry Commission as base maps. Geological boundaries were mapped on air photos and transposed onto the base maps. The access to the Upper Huon square was good but accessibility was not so good in the Arve River square due to lack of roads and the presence of thick rain forests. The geology of the latter square in the inaccessible parts consisted of making series of traverses across the Arve valley and noting the disposition of the rocks where these were exposed in the bed of the river.

Topography and Physiography

The topography of the area is typically that of a young to mature river system. The dolerite hills have steep slopes and a positive relief although the highest point does not exceed 2000 feet. The areas of Triassic and Permian rocks not covered by dolerite have been eroded more readily, hence the valley of the Arve River is almost a plains tract in these sediments while the Huon somewhat further downstream from its confluence with the Arve flows through a gorge cut in dolerite. Rapids have developed in the Huon and Arve Rivers where they intersect relatively harder bands of Permian rocks. The Arve shows three distinct stages in its course due to the influence of underlying rock types. It has developed a prominent meander belt in softer Triassic rocks due to barring by the Permian rocks near its mouth, because headward erosion from the Huon River has not yet reached the stage where the

barring rocks have been breached. The Arve is wider where it crosses the Permian rocks because it has tended to carry out lateral erosion of its banks in the relatively harder sediments. The third case occurs further upstream from the meander belt where the river has a comparatively straight course through dolerite on which it appears superimposed. The floor of the Arve valley is covered by a great amount of white sandy alluvium derived by weathering from the Triassic sandstones. The Russell River at Lonnavale similarly appears to have been superimposed on dolerite underlying Permian rocks. The Huon River has had its course altered because of barring by a dolerite dyke on the western edge of the area and a dyke-like dolerite intrusion on the eastern boundary. The Little Denison River, where it crosses the Denison Hill Road has also developed a small meander because of barring by dolerite contacts. The Huon itself flows along such a contact above the Huon Falls. On the flatter plain areas the Huon has built up levee banks which are up to 10 feet higher than the surrounding country. The streams flowing in the dolerite, particularly on the eastern bank of the Huon have cut steep narrow V-shaped valleys. The control of the location of these streams is intrusive contacts and joints in the dolerite.

Vegetation and rock types:

It was noted that on Permian rocks and weathered dolerite the vegetation was in the nature of very thick rain forest. Dolerite covered by little soil occurs as dark patches on the air photographs and is covered with occasional stunted eucalypts, coarse grass and stunted cutting grass tussocks. Dolerite capped hills occur generally as hills with steep slopes forming buttes in many cases. The Triassic sandstones develop a mesa-like physiographic form and are characteristically covered by thick bracken growth with a few stunted trees or by a very thick stunted growth of small stems. The Permian rocks have no characteristic vegetation but photograph white on the air photographs when not covered with thick vegetation cover. The Permian rocks occur in the lower plains and as low rounded hills.

Stratigraphy

The sedimentary rocks of the area belong to the Permian and Triassic periods together with Recent alluvium and river gravels. The Permian and Triassic rocks have been extensively intruded by dolerite of early Jurassic age. A summary of the stratigraphy follows:

Quaternary System	Alluvium and river conglomerate
Jurassic System	Dolerite
Triassic System	Knocklofty Sandstone and Shale
Permian System	Ferntree Formation Woodbridge Glacial Formation Berriedale Limestone Bundella Mudstone Rathbones Siltstone

Permian System:

The oldest rocks occurring in situ in the area belong to the Permian System. The most complete exposed section of the Permian in the area is shown on the western flank of the divide between the Russell River and Little Denison River, west of Lonnavale.

A detailed analysis of this section gives the following sequence:

Ferntree Formation	200′	†	grey mudstones	370′
	30′		coarse sandstone	
	120′		dense grey mudstone	
	20′		Risdon sandstone	
Woodbridge Glacial Formation	85′		grey-white mudstone	290′
	10′		coarse mudstone with erratics and brachiopods	
	55′		grey-white mudstone	
	110′		fairly finely bedded mudstone very rich in Bryozoa	
	6′		tillitic (?) mudstone	
	24′		coarse-grained mudstone with Bryozoa and large *Spirifers*	
Berriedale Limestone	90′		Limestone and calcareous shales	90′
Bundella Mudstone	120′	†	Irregularly laminated shale bands with few fossils at top	120′

Total exposed thickness = 870 feet Permian sediments

Bundella Mudstone:

This name has been given to rocks occurring in the valley of the Little Denison River, which are similar, both stratigraphically and lithologically, to the Bundella Mudstone in the Granton area. These are the oldest exposed rocks and consist of dark shaly mudstones containing many fossils, particularly *Spirifer, Neospirifer* and *Fenestella*. Thin bands of tillite are also present. The lowermost exposed beds of the Bundella Mudstone are not as fossiliferous as the overlying members. These lower rocks are dense, dark, massively bedded and very fine grained with few fossils, some small quartzite erratics, and an appearance of irregular bedding due to weathering.

Within this formation at least one band of a rock similar to the Rathbones Siltstone has been identified. This rock type occurs as a thin band of well laminated, very fine grained, grey sandstone or mudstone containing quartz grains and some feldspathic material. It shows a differentiation into layers due to bands of dark material about 0·5 millimetres in thickness. The dark bands are characteristically covered with a dense layer of white mica (muscovite) similar to the Knocklofty Shales. The thickness of this rock type was not determined accurately. The thickness of the Bundella Mudstone including the Rathbones Siltstone is somewhat greater than 120 feet as the base was not exposed.

Berriedale Limestone:

The Berriedale limestone overlies the Bundella Mudstone. The transition point is marked by dark greenish-brown, unfossiliferous, irregularly laminated shales with occasional erratics. It consists of a dense gray massively bedded limestone rich in brachiopod remains. *Spirifer, Martiniopsis, Fenestella,* pectenids and *Conularia derwentensis* ?

occur abundantly in the rock, together with occasional corals. Erratics of quartzite, schist, and granite are present. There is evidence of deposition of calcite on exposed surfaces. The limestone is impure and smells of hydrogen sulphide when broken. The uppermost beds of this formation consist of a dark greenish, irregularly-bedded calcareous mudstone with *Fenestella, Martiniopsis* and *Spirifer* and some erratics. The total thickness of the Berriedale Limestone in this area is 90 feet.

Woodbridge Glacial Formation:

The Woodbridge Glacial Formation consists of massively bedded, grey to creamy coloured mudstone containing numerous erratics of slate, schist, quartzite and granite. The uppermost beds of this formation are grey in colour with few fossils. Bands of conglomerate are common, together with grey shales containing a few iron-stained fossils. The lower beds contain dark shale bands very rich in *Fenestella* and other Bryozoa. Coarser bands contain many Brachiopods and some *Stenopora*. There also appear to be fossils concentrated in a band immediately beneath the base of the Ferntree Formation. A mottled zone appears in the Woodbridge Glacial Formation about 100 feet below the Ferntree Formation near Judbury. The total thickness of the Woodbridge Glacial Formation is 290 feet.

Ferntree Formation:

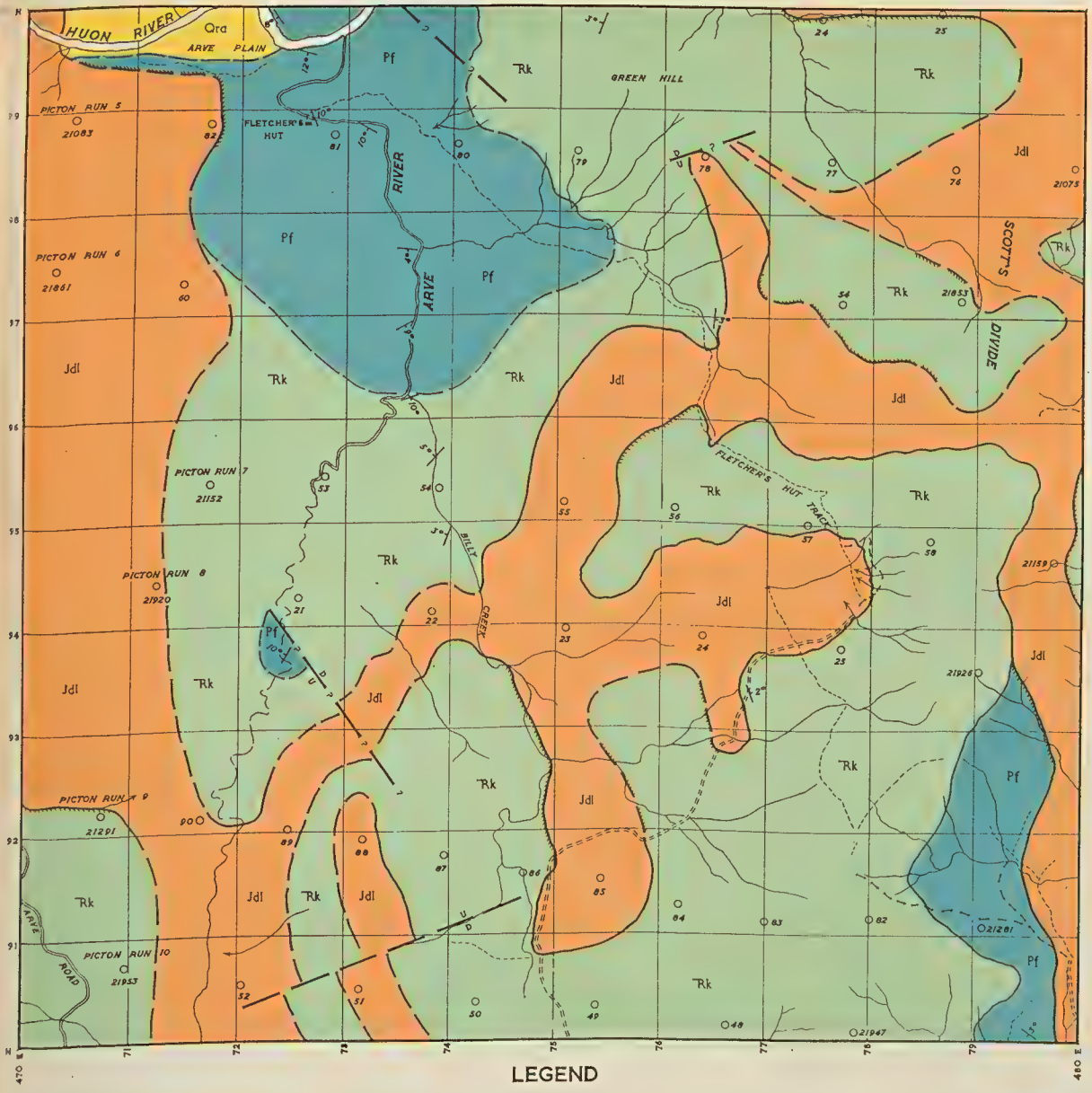
The Ferntree Formation is overlain by the Knocklofty Sandstone the base being shown by the presence of the Risdon Sandstone member. This sandstone occurs as a band of massive, current-bedded, quartzose sandstone of very irregular grainsize containing erratics which may attain 6 inches in diameter. The erratics are mainly quartzite. Its thickness is about 20 feet. The mudstones are generally uniformly massively bedded with small erratics and alternations of shaly bands. The rock is fine grained containing many small irregularly shaped erratics and many dark carbonaceous-looking streaks which tend to give the rock its greyish colour. Occasionally large erratics of quartzite, slate, schist and granite are present. Fossils are very rare or absent. At 120 feet above the base of the Ferntree Formation another band of sandstone resembling the Risdon Sandstone outcrops. The second band of sandstone is about 30 feet in thickness. The total thickness of the Ferntree Formation in the area is at least 450 feet and may be 600 feet.

The Ferntree Formation is overlain by the Knocklofty Sandstone and Shale. It does not appear that any rocks representing the Cygnet Coal Measures occur in this area although a fine grained, dark, micaceous shale in the Arve River near the base of the Triassic may represent this formation.

TRIASSIC SYSTEM:

The Triassic rocks overlie the Ferntree Formation with a slight disconformity. This was not seen in detail in the area.

ARVE RIVER



LEGEND

- FAULT WITH DOWNTHROWN SIDE INDICATED
- FAULT – POSITION APPROXIMATE
- FAULT INFERRED
- FORMATION BOUNDARY

Dolerite Boundaries

- CONCORDANT SILL
- DISCORDANT INTRUSIVE BOUNDARY

- STRIKE AND DIP
- ROADS
- VEHICULAR TRACK
- TRACK
- DISUSED TRAMWAY

Quaternary System

RECENT SERIES

- Qra ALLUVIUM

Triassic System

- Rk KNOCKLOFTY SANDSTONE AND SHALE

Permian System

- Pf FERNTREE MUDSTONE

IGNEOUS ROCKS

Jurassic ? System

- Jdl DOLERITE

KEY MAP SHOWING MAGNETIC VARIATION

Base map by courtesy of FORESTRY COMMISSION Hobart

SCALE

0 1 2 MILES

0 1 2 3 4 5,000 10,000 FEET

MAPPED BY R. J. FORD JAN.–FEB. 1955

GEOLOGY OF ARVE RIVER AREA

1. BIBLIOGRAPHY:

BLAKE, F., 1935 — Report on country along route of Craycroft Track. **Unpublished report of Mines Dept.**

FORD, R. J., 1956 — Geology of the Upper Huon-Arve River Area. **Pap. Proc. Roy. Soc. Tas.,** Vol. 90, pp. 147-156.

2. STRATIGRAPHIC TABLE:

SYSTEM	FORMATION	ROCK TYPE	THICKNESS (in feet)
Tertiary and Quaternary		**Erosion interval**	
Early Tertiary?			
Jurassic?		**Strong epeirogeny and faulting**	
Triassic		Dolerite sills and sheets	800
Permian	Knocklofty	Sandstone and shale	370
	Ferntree	Mudstone	290
	Woodbridge	Glacial formation	

3. LOCALITIES OF SPECIAL INTEREST:

Thin sill of dolerite	476500E. 698000N.
Dolerite sill	477000E. 693800N.
Ferntree Mudstone showing presence of strike fault	472500E. 693700N.
Faulted Triassic rocks	470300E. 691000N.

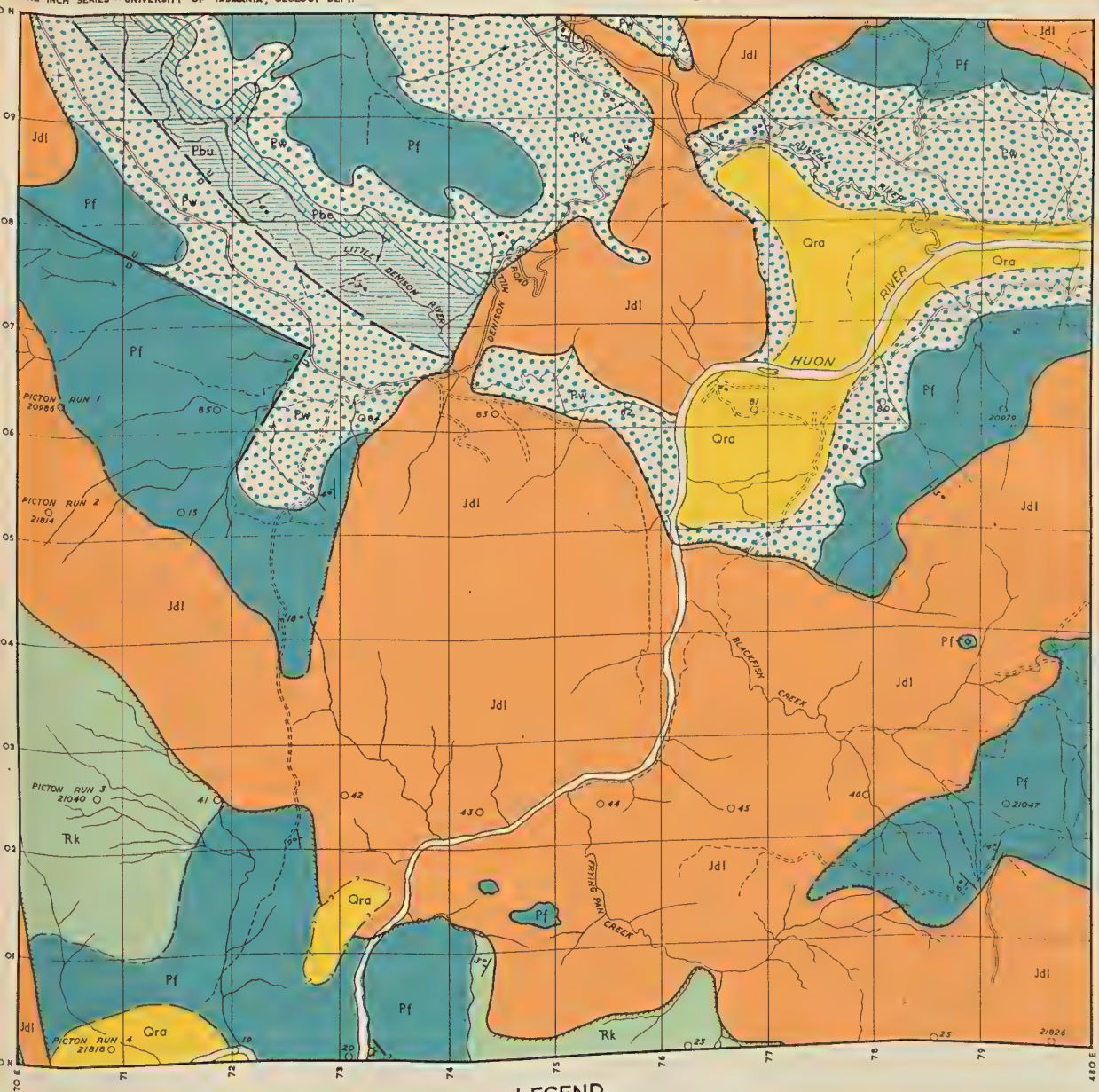
4. PHYSIOGRAPHY:

Note control of Arve River by rock types.	
Waterfalls in Ferntree Mudstone	473600E. 697500N.
Weathered dolerite	471000E. 696000N.

GEOLOGY OF TASMANIA
ONE INCH SERIES – UNIVERSITY OF TASMANIA, GEOLOGY DEPT.

UPPER HUON

4770



LEGEND

- FAULT WITH DOWNTHROWN SIDE INDICATED
- FAULT – POSITION APPROXIMATE
- FAULT INFERRED
- FORMATION BOUNDARY

Dolerite Boundaries

- CONCORDANT SILL
- DISCORDANT INTRUSIVE BOUNDARY
- STRIKE AND DIP
- ROADS
- VEHICULAR TRACK
- TRACK
- HORIZONTAL DIP
- PHOTO CENTRE

Quaternary System
RECENT SERIES

- Qra ALLUVIUM

Triassic System

- Rk KNOCKLOFTY SANDSTONE AND SHALE

Permian System

- Pf FERNTREE MUDSTONE
- Pw WOODBRIDGE GLACIAL FORMATION
- Pbe BERRIEDALE LIMESTONE
- Pbu BUNDELLA MUDSTONE AND RATHBONE'S SILTSTONE

IGNEOUS ROCKS
Jurassic ? System

- Jdl DOLERITE

KEY MAP SHOWING MAGNETIC VARIATION

Base map by courtesy of FORESTRY COMMISSION Hobart

SCALE
0 1 2 3 4 5000
2 MILES
10,000 FEET

MAPPED BY R. J. FORD JAN. 1958

GEOLOGY OF UPPER HUON AREA

1. BIBLIOGRAPHY:

BLAKE, F., 1935 — Report on country along route of Craycroft Track. **Unpublished report of Mines Dept.**

FORD, R. J., 1956 — Geology of the Upper Huon-Arve River Area. **Pap. Proc. Roy. Soc. Tas.,** Vol. 90, pp. 147-156.

2. STRATIGRAPHIC TABLE:

SYSTEM	FORMATION	ROCK TYPE	THICKNESS (in feet)
Quaternary and Tertiary		**Erosion interval**	
Early Tertiary?		**Strong epeirogeny and faulting**	
Jurassic?		Dolerite sills and sheets	300+
Triassic	Knocklofty	Sandstone and shale	800+
Permian	Ferntree	Mudstone	370+
	Woodbridge	Glacial Formation	290
	Berriedale	Limestone	90
	Bundella	Mudstone	120+

3. LOCALITIES OF SPECIAL INTEREST:

Berriedale limestone with fossils	473500E. 708000N.
Intrusive contacts of dolerite	473250E. 701250N. 473250E. 706500N.
Dolerite dyke	475000E. 707800N.
Isolated sedimentary blocks on dolerite	474300E. 701700N. 478800E. 703800N. 475000E. 701400N.
Weathering of dolerite	473500E. 701500N. 79500E. 700000N.

Knocklofty Sandstone and Shale:

The Triassic rocks in this area have been provisionally placed in this Formation. The lowermost beds consist of the typical buff to red coloured, fine grained shales containing numerous muscovite mica flakes and occasionally graphite particles on the bedding planes. Interbedded with these are the typical cliff forming sandstone horizons. At least four cliff forming sandstone horizons are present in the section on the western face of Green Hill. The sandstones are massive, strongly cross-bedded, glistening, uniform grained, quartzose sandstones, which may be iron-stained, containing concretionary structures and occasionally mud pellets. The leached sandstones are very white and weather to give a very sandy soil which supports a heavy growth of bracken fern. The maximum thickness of this formation in the area is at least 800 feet with the top beds being omitted.

JURASSIC ? SYSTEM:

Dolerite

The extensive intrusions of dolerite took place after the deposition of the Triassic rocks, probably in the lower Jurassic. The intrusions are sill-like and dyke-like in form. The dolerite appears to be sill-like mainly when intruded into the Triassic and dyke-like in the Permian rocks. The dolerite intrusions are the main structural controls in the area.

QUATERNARY SYSTEM:

Alluvium and river conglomerate

The youngest sediments in the area appear as alluvium derived from the weathering of the rocks and an extensive development of river gravels and conglomerate occurring on the banks of the Huon. This occurs in the form of three river terraces, the highest of which is approximately 150 feet above the Huon River in the area about half a mile downstream from the Arve River. The conglomerate consists mainly of well rounded pebbles and boulders of quartzite and siliceous conglomerate, the largest diameter being about 12 inches. Pebbles in the bed of the Huon show imbrication when exposed. Near the Huon Falls where the river has cut through the dolerite the conglomerate consists of pebbles of dolerite which have become cemented to form a hard conglomerate.

GEOLOGICAL STRUCTURE

The structure of the area is controlled mainly by the intrusion of the Jurassic dolerite, associated with contemporaneous faulting. Other post-dolerite faults, the age of which cannot be determined decisively, are also present. These have been established in the Upper Huon square because access is easier. In the Arve River square evidence exists for the presence of at least two post-dolerite faults. Other faults are present but lack of suitable evidence does not allow for their correct placement.

Dolerite Occurrences:

The dolerite has intruded the sediments of the area in a very complex manner. Three types of dolerite contact, with the country rock, can be recognised. These are:

1. Sill-like contact.
2. Dyke-like contact.
3. Post intrusive fault contact.

The first two types are the most common in the area. The post intrusive fault has been doubtfully identified in the area. Because of the complexity of the intrusions, in any particularly intrusive body, it frequently happens that the contacts with the country rock are both dyke-like and sill-like.

The dolerite on the northern boundary of the Upper Huon sheet occurs, as a concordant intrusion in the Woodbridge Glacial Formation, in the bed of the Russell River. East of this the boundary crosses the hillside, sharply transgressing the Woodbridge and Ferntree Formations, as a dyke-like intrusive contact. At the north-east corner of the area the dolerite occurs as a concordant intrusion into the Ferntree Formation. Along grid line 709000 N the dolerite becomes dyke-like near the junction of the Lonnavale-Denison Hill roads. The western contact is dyke-like, crossing the Denison Hill Road at the first sharp bend south of the Lonnavale turn-off, and extending to the top of the hill where an outcrop of Risdon Sandstone appears to be covered by a sill-like contact. This contact extends as a steeply dipping discordant contact which is exposed on the hillside on the north-east bank of the Little Denison River. The contact crosses the road near the bridge over the Little Denison River and bears almost due south from here along a spur almost to the last substantial hut on the Weld River track. A quarry has been opened in the baked Permian rocks of the Woodbridge Glacial Formation on this contact at the beginning of the Forestry road to the Standard Case Co. Mill. The Permian here shows a drag dip to the west. From grid line 714000 N this contact becomes sill-like in nature overlying the Ferntree Formation and bearing north-west to edge of the area. Further south this same intrusive mass has a dyke-like contact with the Knocklofty Sandstones and Shales at the top of the hill. At the base of this hill the mass has a discordant contact with the Ferntree Formation. The contact is exposed in the bed of the Huon River near grid line 701000 N. The Ferntree Formation here has been baked and silicified by the intrusion; the contact of which shows columnar jointing and dips very steeply in a northerly direction. On the eastern bank of the Huon the contact bears east to the northern slopes of Green Hill. On the eastern side of Green Hill the contact, which is now in the Knocklofty Sandstones and Shales, swings approximately south, still showing fine-grained dolerite. The eastern side of this intrusive dolerite mass beginning at the junction of the Lonnavale and Denison Hill roads appears to be dyke-like in nature intruded into the Woodbridge Glacial Formation. Near the Huon River the contact appears to be sill-like but this could not be determined decisively due to the presence of the overlying river conglomerate. The Huon River between grid lines 706000 N and 707000 flows along the contact of the dolerite and Woodbridge Glacial Formation.

The Little Denison River flows in Woodbridge Glacial Formation rocks for approximately one and a half miles before its confluence with the Huon River. In this area the dolerite is sill-like over the Woodbridge Glacial Formation north of the Little Denison River. The dolerite then becomes part of the dyke which bars the upper reaches of the Little Denison River. On the southern bank of the river the dolerite swings away in an easterly direction and eventually is cut by the Huon River near grid line 705000 N. The nature of the contact on the southern bank of the Little Denison could not be determined accurately although the outcrop to contour relationship suggests that it may be sill-like in nature. On the eastern bank of the Huon at this point the dolerite is strongly discordant and follows the course of a stream towards the tops of the hills on the eastern edge of the area. The dolerite occurs as a slightly transgressive sill overlying rocks of the Ferntree Formation on the tops of these hills. To the north-east, slightly outside the area mapped this sill becomes strongly discordant, crosses the Huon River, and ultimately connects with the dolerite sill in the north-eastern corner of the area. The course of the river has been modified slightly where it cuts through the dolerite. In the south-eastern part of the Upper Huon sheet the dolerite shows an intrusive dyke-like contact in Permian rocks. This contact becomes sill-like near the junction of the new Forestry Road south-west of Glen Huon. The dolerite shown in the south-western corner of the Upper Huon sheet is part of a dolerite dyke which extends at least two miles connecting the dolerite intrusion south of the Huon with the dolerite mass which runs north-west on the northern edge of the Knocklofty Sandstones and Shales Formation. This dyke appears to be about 300 yards wide and occurs as a topographic linear of positive relief. On the southern boundary of the Upper Huon sheet the dolerite occurs as a sill-like intrusion overlying the Ferntree and part of the Knocklofty Sandstones and Shales. It has not been determined that this mass is part of the larger mass occurring a few hundred yards further north. It can be seen, however, that most of the dolerite occurs as one large intrusive mass with the various types of contacts described above. The dolerite appears to be massive and well jointed. The tributaries on the eastern bank of the Huon appear to be controlled by jointing in the dolerite and have cut deep V-shaped valleys. There does not appear to be any faulting associated with the streams because apparently massive dolerite occurs in their beds. The eastern bank of the Huon where it cuts through the dolerite in the gorge does not have any debris from the river, however, the western bank is covered by coarse river conglomerate containing rounded boulders of quartzite and silicified conglomerate up to 150 feet above the river. The dolerite on the western bank is covered by thick rain forest which may mean that this dolerite has undergone a greater amount of weathering than the dolerite of the eastern bank, or may be due solely to the covering of river wash. Scattered in patches over the dolerite are small areas of silicified Permian rock which occur apparently as small erosion residuals. They may represent the remnants of the tops of the intrusions or they may represent stoped blocks of sediment which have fallen into the magma. One particularly interesting occurrence at 704000 N and 479000 E consists of a small pipe of dolerite intruded through one of these blocks.

The dolerite intrusion in the Arve River sheet does not appear to be as complex as the previous type. Here again the dolerite appears as a single intrusive mass. In the north-eastern part of this area the dolerite has intruded the Knocklofty Sandstones and Shales as a sill which branches from the dyke-like intrusion in the south-east corner of the Upper Huon sheet. The sandstone has been baked to form a white crystalline quartzite. On Green Hill in the central northern area of the Arve River sheet the dolerite occurs as the sill intruded into the Knocklofty Formation from the Upper Huon sheet. On the southern part of Green Hill the Triassic rocks lie in contact with the dolerite hence it appears that the Triassic was faulted by the intrusion of the sill in this area and the upthrown block of Triassic has since been eroded away. On the western boundary of the Arve River sheet the dolerite is intruded into the Ferntree Formation as a dyke-like intrusion and appears to cap the divide between the Arve and Picton Rivers. It appears to be in the form of a transgressive sill. The general structure of the Arve River Valley is that of a series of beds dipping at a low angle in a westerly direction. The dolerite has been intruded into these beds as a sill overlying the Knocklofty Sandstones and Shales and dips at a low angle upstream; thus the bed of the Arve River near the southern boundary is cutting dolerite but as one follows the river north, the dolerite outcrops higher on the banks of the river while the river bed itself is cut in Triassic and Permian sediments. The sill was not mapped in accurately because of thick undergrowth but there appears to be two sill-like intrusions into the Triassic rocks in the south-western part of the area. These structures can be seen along the track to Mt. Picton on the eastern side of the Arve River. The western bank of the Arve valley is made up of dolerite which has both a sill-like and dyke-like contact. This can be seen where the Arve road begins to climb up the eastern face of the divide between the Arve and Picton rivers. The highest part of this divide lies to the west of the area and consists of the Knocklofty Sandstones. The dolerite appears to make up the eastern part of the divide running northwards as a transgressive sill overlying the Permian and Triassic rocks of the Arve valley.

The south-eastern quarter of the Arve River sheet shows the general structure of a big transgressive dolerite sill which is intruded on the contact of the Permian and Triassic formations. This intrusion becomes dyke-like in form on the top of the hill on Fletcher's Hut track. Elsewhere the intrusion underlies the Knocklofty Sandstones and Shales except in the south-eastern corner where it transgresses the Ferntree Formation with an apparently strongly discordant contact. The edge of this intrusion on the eastern part of the area is discordant and cuts a small outcrop of Triassic rocks overlying the Ferntree Formation. North of Fletcher's Hut track the dolerite lenses out as a thin sill intrusive into the Knocklofty Sandstones and Shales. The sill outcrops on the top of a prominent band of cliffs in this formation and is overlain by more sandstones. This structure is similar to that on the northern slope of Green Hill. The dolerite in this form connects with the sill in the north-eastern corner of the sheet where the sandstone has been baked to a quartzite by the overlying dolerite.

The complexity of the dolerite intrusions is shown by the upper reaches of the Little Denison River where in one section a dolerite outcrop approximately one foot in diameter and showing a baked contact was seen in the Bundella Mudstone. No dolerite outcrops elsewhere until the main dolerite intrusive body about a quarter of a mile away. This evidence suggests that even in the apparently homogeneous sedimentary blocks there could well be hidden dolerite intrusions. In a similar manner a small irregularly shaped intrusion occurs in the Huon River downstream from the Arve.

Faulting

Numerous small faults exist in the Permian rocks near the mouth of the Arve River, as shown by the presence of many reversals of dip. The relation of these to the dolerite is indeterminable. The Triassic rocks along the Arve Road also have many small faults, shown in cuttings by reversal of dip. These strike generally north-east south-west. There is much dolerite in this area and its intrusion most probably was responsible for these disruptions. Where exposed the fresh dolerite is dense and fine grained.

Little evidence was seen showing the presence of post-intrusive faulting where the dolerite had been displaced. On the southern part of the Arve River sheet the upper dolerite sill capping the eastern flank of the Arve River valley from the air photographs was seen to be displaced by a linear running approximately north-east south-west. This could not be checked accurately on the ground but it appears to be a post-intrusive fault. To the north of this fault another fault running approximately north-west south-east exists. The actual position of this fault is not exactly known but evidence is that on going up the Arve River valley from the Huon the sequence is Ferntree Formation, Knocklofty Sandstones, Ferntree Formation, Knocklofty Sandstone and dolerite. All these rocks have a component of dip upstream. The fault has been responsible for repeating the Permian in the sequence and this repetition appears to exist across a line which extends off a strong linear developed in the sandstones on the button grass plain on Picton Run Nine 21287. The drainage of Billy Creek and a small creek to the south-west of it are also strongly delineated in a north-west south-east direction.

In the Upper Huon area faults have been found cutting the Permian sediments. The largest fault follows the course of the Little Denison River valley in a north-west south-east direction. As a result the Bundella Mudstone on the north-east side of the valley is upthrown against rocks of the Woodbridge Glacial Formation to the south-west. The throw of this fault is about 400 feet but the age is puzzling because it does not appear to cut the dolerite to the south-east on the Denison Hill road. The course of the Little Denison river has been controlled by the presence of this fault. In the same area another fault running in approximately the same direction occurs south of the Forestry road. In this the Ferntree Formation rocks are thrown down against Woodbridge Glacial Formation rocks. The throw of this fault which is shown on the air photos by a strong linear is about 100 feet. The age of this fault is also indeterminate. There may be a doubtful third fault in this group bearing approximately north-east south-west with Woodbridge Glacial Formation rocks in contact with the Ferntree Formation. In the bottom

of the valley the Risdon Sandstone outcrops on the downthrown side of the fault. On the upthrown side the Risdon Sandstone outcrops high on the hill to the east of the road which leads out to the south-west corner of the square. However, the distribution of Risdon Sandstone may be due to the dip of the rock across the valley. The southern end of this fault may cut the dolerite boundary. This is hard to prove and if this is the case then the fault is certainly post-intrusive. Another doubtful small fault may exist along the line of a small creek flowing down 472000 E in the south of the Upper Huon square with the western block as the downthrown side. The rocks on the eastern block appear to have a greater dip than those on the western block and the occurrence of a sandstone which may be the Risdon Sandstone does not leave enough room for the remainder of the Ferntree Formation which underlies the Triassic rock to the west. The Knocklofty Sandstone and Shale on the Arve road in the southern part of the area is cut by numerous small faults which have probably been caused by the intrusion of the Jurassic dolerite. It is impossible to determine the relation between these and the dolerite contacts.

General Structure:

The dolerite has caused the splitting up of the sediments into discrete blocks. These can be recognised in the north-east and north-west of the Upper Huon square and in the south-east and south-west of the above. The south-west block is terminated by a north-west south-east trending dyke.

The Arve valley consists of one block surrounded by continuous dolerite with a discrete block of Triassic rocks in the south-west. The eastern edge of the area consists mainly of massive siliceous Triassic sandstone which overlies the dolerite concordantly. This sandstone rises on going from south to north and reaches its highest point on Scott's Divide. The sandstone has either been strike faulted to different heights or has been raised to different heights by the intrusion of the dolerite as different blocks. No sign of post-intrusive faulting has been definitely found in this area and all contacts which have been pin-pointed have proved to be intrusive contacts with baked sandstone hence it would appear that the Triassic sandstones on Scott's Divide have been pushed to different levels by the intrusion of the Jurassic dolerite. The power of the dolerite to wedge blocks out of the Triassic sandstone is shown quite clearly by the sill on the northern slopes of Green Hill.

Acknowledgments

My thanks are due to the Hydro-Electric Commission for whom the field work was carried out and who made equipment available for work in the area.

Locality Index

	Internat. Grid Reference K/55 Quadrangle		S. Lat.	E. Long.
Arve River	Picton	87	43° 4′	146° 51′
Billy Creek	Picton	87	43° 7′	146° 51′
Green Hill	Picton	87	43° 4′	146° 51′
Little Denison River	Picton	87	43° 0′	146° 50′
Russell River	Styx	81	42° 59′	146° 51′
Scott's Divide			43° 7′	146° 54′

THE MAGNETISATION OF THE MESOZOIC DOLERITES OF TASMANIA

By

E. Irving

National University, Canberra

(With 5 Text Figures)

(Communicated by Professor S. Warren Carey)

Abstract

The Mesozoic dolerites of Tasmania have an almost vertical magnetisation. The magnetic pole consistent with this magnetisation is situated 10° S.E. of Tasmania. The stratigraphical record of Australia at this time suggests climatic conditions indicating a high geographical latitude agreeing with the high geomagnetic latitude, and this provides qualitative evidence in support of the supposition that some time in the later Mesozoic the geomagnetic field, when averaged out over several thousand years, was approximately coincident with the axis of rotation.

1. Introduction

Igneous rocks extruded over a land surface or injected into pre-existing formations at temperatures of over 1000° C acquire a "thermo-remanent" magnetisation in the direction of the geomagnetic field on cooling down to normal temperatures. If this direction remains unchanged throughout subsequent geological time the rock is said to be magnetically stable, and the measured directions of magnetisation may be used to determine the direction of the Earth's magnetic field in the past and thus also the approximate position of the geomagnetic pole. It has been shown previously that palaeomagnetic evidence (Hospers (1955)) and the comparison of this with palaeoclimatological data (Irving (1956)) suggests that the geomagnetic field when averaged out over several thousand years has been coincident with the Earth's axis of rotation. These new results from Tasmania are shown to be consistent with this view. The results are compared with palaeomagnetic data from Europe and their relevance to the theory of continental drift is discussed.

In addition to the directions of magnetisation, the intensity of magnetisation and susceptibility of the rocks have been measured and these are given in Table III.

2. The Tasmanian Dolerites

The dolerites are intrusive through folded Precambrian to Lower Devonian rocks and into 2000 to 4000 feet of flat-lying sediments of Lower Permian to Upper Triassic age (possibly late Carboniferous to Lower Jurassic) where they take the form of transgressive sheets and

sills. Their original extent prior to denudation was probably about 15,000 square miles and their average thickness about 1000 feet (Edwards, 1942). The enclosing sediments are tilted at low angles, usually not more than 10°; this was caused largely by Lower Tertiary block faulting, but the intrusion of the dolerite may have contributed in some areas. The direction of tilt varies but a dip of about 5° towards the south-west seems to be dominant. A statistical mean of the dips might be expected to be in this direction at a small angle. No correction has been applied to the magnetic results since regional mapping has not been sufficiently complete to allow reliable corrections to be made. A small error may have been introduced through this assumption.

The dolerites have a tholeiitic composition. Their petrography has been described previously by Edwards (1942) and Jaeger and Joplin (1955).

The youngest sediments cut by the sills are Upper Triassic and possibly in some cases Lower Jurassic in age. Intrusion was completed before the epeirogenic faulting of the Early Tertiary, and the dolerite was deeply dissected before the deposition of the Tertiary (probably lower Tertiary) lake sediments which in places overlie them. The sills therefore date from the Jurassic or Cretaceous.

3. The Directions of Magnetisation

It has been noticed previously (Jaeger and Joplin (1955)) that several bore-cores in dolerite from the Great Lake area have almost vertical magnetisation. The present work demonstrates that this is generally characteristic of all the Tasmanian sills.

Sampling and Measurement. In some rock formations whose magnetic properties have been studied it is often necessary (because of poor exposure or the rarity of suitable rock types) to limit the observations to certain horizons from which many samples are collected in order to obtain an accurate mean result. In contrast, the Tasmanian dolerites are well exposed and are always suitable for magnetic study; clearly the best way of obtaining accurately the average magnetisation of all the intrusions is to spread the samples as evenly as possible through their thickness and areal extent. The thirty collection sites, mostly quarries and road-cuttings, from which fresh material can be obtained are distributed over the dolerite outcrop covering an area of about 9000 square miles (Figure 1). Two samples have been obtained at each site. Orientation is by standard geological methods. Small cylinders $\frac{7}{8}''$ in height and diameter are machined from these samples with non-magnetic tools, orientation being preserved during the process.

The magnetisation of the rock cylinders is measured by an astatic magnetometer, which has been built by the author and is housed in a special non-magnetic hut at the Australian National University, Canberra. The instrument is set in Helmhotz coils which eliminate the Earth's magnetic field, and is responsive to vertical field gradients, the sensitivity being $3{\cdot}69 \times 10^{-7}$ gauss per cm. per mm. deflection, these deflections being observed by means of lamp and scale. The period is 2·5 seconds. The cylinder is held in a goniometer device at about 5 or 6 cms. beneath

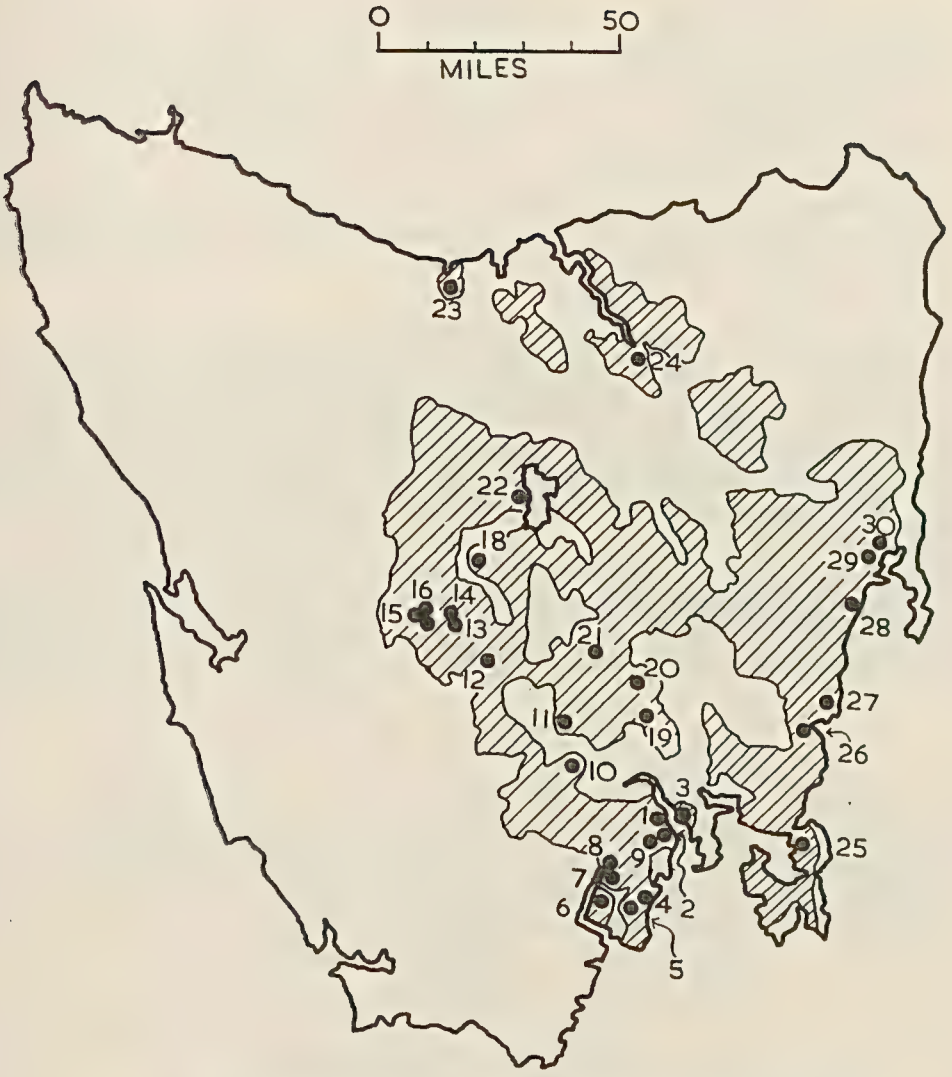


FIG. 1.—*The distribution of sampling sites.* The localities are numbered as in Table III and the area of the dolerite outcrop is shaded. The locality south of 16 should be numbered 17.

the magnetometer, and may be adjusted to the angle at which maximum response from the instrument is obtained. The instrument is so arranged that the angles of dip and declination can then be read directly from the goniometer scales, and from the magnitude of the deflection the magnetic intensity can be calculated. The susceptibility is measured by applying fields to the specimen by the Helmhotz coils. The short instrumental period allows very rapid measurement, each specimen requiring about three minutes. It can be shown experimentally that when the distance

from the magnetometer is greater than 4·5 cms. it is adequate to represent the magnetisation by a dipole situated at the geometrical centre of the rock cylinder, the direction of the dipole being parallel to the mean magnetisation and its strength equal to the total intensity. The complications due to the shape of the specimen and the inhomogeneity of magnetisation which have been discussed previously (Irving (1954)) do not arise.

The direction of magnetisation in these cylinders is measured to an accuracy of 3° and the field orientation is correct to 5°, but these errors are random and will be to a large extent lost in the mean of pairs of samples at each site. The average difference in direction between these pairs is 13° (see Table III).

The directions of magnetisation. The directions are specified by the angles of dip, θ, and declination, ϕ, with respect to the north-seeking polarisation. With x, y and z-axes respectively North, East, and downwards, θ is the angle between the direction and the horizontal or xy-plane, and ϕ is the angle between the x-axis and the projection of the direction on this plane. Declination is measured clockwise of geographic North, and the dip is regarded as negative when above, and positive when below, the horizontal.

The directions at each site, as a mean of two samples, are given in Table III and plotted in Fig. 2. The vertical component of magnetisation is always upwards (normal) and no reversals occur. The mean dip θ_m and declination ϕ_m from all sites is obtained from the formulae

$$\tan \theta_m = Z/(X^2 + Y^2)^{\frac{1}{2}}, \quad \tan \phi_m = Y/X,$$

where $X = \Sigma \cos\theta \cos\phi$, $Y = \Sigma \cos\theta \sin\phi$, and $Z = \Sigma \sin\theta$.

The scatter of directions is expressed by the probable error (Watson and Irving (1955)) which is the semi-vertical angle in degrees of a cone described about the mean direction within which 50 per cent of the observations lie. This is given by

$$\text{probable error} = 67{\cdot}5\ k^{-\frac{1}{2}}$$

where N is the number of observations,

$$k = \frac{N - 1}{N - R}, \quad \text{(Fisher (1953))}$$

$$\text{and } R^2 = X^2 + Y^2 + Z^2.$$

The error c in defining the mean direction is obtained from the relationship (Fisher (1953)),

$$\cos c = 1 - \left\{\frac{N - R}{N}\right\}\left\{P^{-1/N-1} - 1\right\}$$

where c is the semi-vertical angle of the cone around the mean direction outside which the true mean may lie with a probability P. The mean directions θ_m and ϕ_m are given in Table I together with these parameters.

TABLE I.

The mean direction of magnetisation of the Tasmanian dolerites.

No. of sites.	ϕ_m	θ_m	R	k	Probable error.	c $P = 0{\cdot}05$
30	325	—85	29·398	48·2	10°	4°

Magnetic Stability. The following test shows that the magnetic directions in the dolerite have remained unaltered since the Lower Tertiary. At Cartwright Point south of Hobart there is a fault scarp breccia of Lower Tertiary age (Carey, S. W., private communication) containing dolerite boulders with a highly irregular arrangement (Figure 3). If the magnetisation of these dolerite boulders was imposed after formation of the breccia, the directions should be parallel from boulder to boulder, but if the directions have remained unaltered they will be widely scattered. Directions from nine boulders are plotted in Figure 4 and it can be shown statistically that these are random. Clearly the directions of magnetisation have remained unchanged since before the formation of this breccia, so there is good reason to suppose that they were acquired during cooling in the Jurassic or Cretaceous.

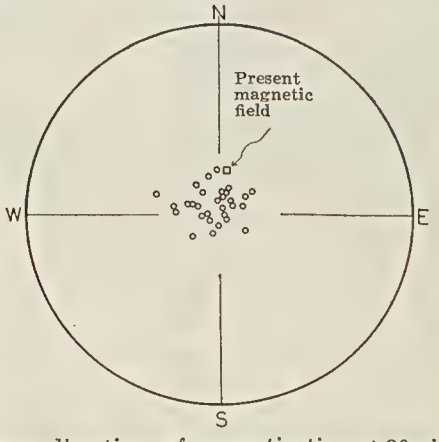


FIG. 2.—*The mean directions of magnetization at* 30 *sites in the dolerites of Tasmania.* The plane of the projection is the horizontal plane in Tasmania and the north-seeking polarisations are plotted on the upper hemisphere.

During cooling the Curie point would not be reached in all intrusions at the same time, and the fossil directions may differ due to the secular variation of the Earth's magnetic field; this may explain part of the scatter in Figure 2. It is difficult to estimate the length of this record. The emplacement of such a large volume of magma in the various sills

(Edwards (1942) estimates 3000 cubic miles) must have taken many thousands of years although the time involved is short geologically speaking as Edwards suggests. Even the solidification of the thicker sills took thousands of years (Jaeger and Joplin (1955)). It seems likely therefore that the mean direction in Table I is the ancient direction of the geomagnetic field averaged out over at least several thousand years and probably very much longer.

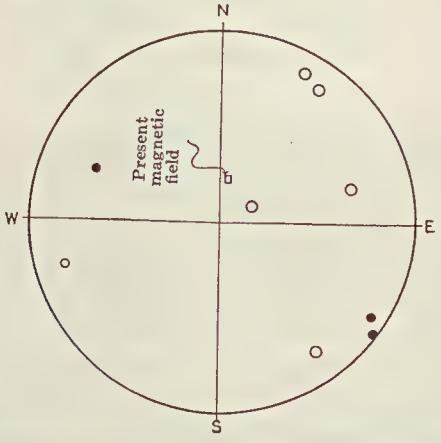


FIG. 4.—Directions of magnetisation in dolerite boulders taken from a lower Tertiary breccia. The plane of the projection is the horizontal plane in Tasmania. North-seeking polarisations are plotted as circles in the upper hemisphere and as dots in the lower hemisphere.

4. THE POSITION OF THE POLE IN THE PAST.

The relationship of the geomagnetic pole to the Earth's axis of rotation. There are strong reasons for supposing that in the past the Earth's magnetic field, when averaged out over several thousand years, centred around the axis of rotation. This is true for the past 20 million years since the mean direction observed in Upper Tertiary and later rocks in Europe is consistent with a geocentric dipole field; that is, the mean direction is comparable to that which would be produced by a dipole situated at the centre of the Earth and directed along the present axis of rotation. (Hospers (1955)). This dipole may have reversed in polarity several times (Hospers (1954)). The support for assuming the correlation of the mean geomagnetic and geographic axes for more remote geological epochs is provided by the comparison of palaeomagnetic and palaeoclimatological data (Irving (1956)). If this correlation is correct, the ancient co-latitude p and the mean magnetic dip θ_m will be connected by the following relationship

$$\tan \theta_m = 2 \cot p,$$

Fig. 3.—The breccia at Cartwright Point near Hobart containing boulders of dolerite.

and the evidence of past climates from which an estimate of P can be made should be compatible with the dip measured in rocks from the same region. It has been shown previously (Irving (1956)) that the data from Europe is in as good agreement as can be expected from the qualitative nature of the palaeoclimatological data.

From the above relationship and the value of θ_m in the dolerites (Table I) the following palaeomagnetic latitudes are obtained assuming negligible relative movement between the different parts of Australia:

Tasmania 80°
Victoria 75°
South Australia 65°
South-Eastern Queensland 60°

The climate during the Jurassic and Cretaceous seems to have been generally warmer than at present, and nowhere in the world has there yet been found evidence of such profound refrigeration as occurred at the end of the Palaeozoic and in the Pleistocene. There is, however, evidence of cool conditions in Australia which is in contrast to evidence of warm conditions so widespread in other parts of the world at this time and which would therefore indicate a high geographical latitude for Australia.

1. The vegetation of the Jurassic and coal-swamps probably grew in a cool moist climate (David (1950), p. 476).
2. In western N.S.W. and South Australia there is evidence of glaciation. Large striated erratics of a great variety of rock types occur embedded in shales of Cretaceous age. (Ward (1916), Woolnough and David (1926), Kenny (1934).) These erratics were probably transported by icebergs.
3. Examples of glauberite pseudomorphed by opal (Kenny (1934)) indicate deposition in a cool shallow sea. (David (1950), p. 515.)
4. The marine invertebrates of eastern Australia have affinities with cold-water faunas (Whitehouse (1926)) although at times they are of more cosmopolitan aspect.
5. Large coral reefs and rudist lamellibranchs characteristic of the warm Tethyan sea are absent.
6. Dinosaurs, which are generally regarded as warm climate animals, lived in Australia at this time, and this would indicate that the climate was not continuously cold but that there were warm periods comparable to the warm interglacials in the Pleistocene.

The balance of the palaeoclimatological evidence suggests cool conditions during the later Mesozoic in Australia and this is consistent with the high geomagnetic latitudes given by the results from the Tasmanian dolerites suggesting that the mean geomagnetic and rotational axes of the Earth were coincident at this time.

The ancient pole position. The geomagnetic pole is that point on the Earth's surface at which the geomagnetic axis emerges, and its average position during the intrusion and cooling of the dolerite sills

may be calculated from the magnetic results since the mean magnetic direction represents a line of force in the field of the geocentric dipole. The scatter in the magnetic observations will give an uncertainty to this pole position. The method of calculating this has been given previously (Irving (1956)). The uncertainty in co-latitude δp will be slightly greater than the error δm in the direction of declination. The co-ordinates and errors of the ancient pole position are given in Table II and plotted in Figure 5 (point 8).

TABLE II.

The Pole position in later Mesozoic times.

Present-day Tasmania		Ancient Pole co-ordinates		Errors $P = 0{\cdot}05$.	
Lat.	Long.	Lat.	Long.	δm	δp
42° S	147° E	50° S	157° E	1°	8°

If the correlation of geomagnetic and rotational axes is correct, this represents the position of the geographic pole relative to Tasmania at the time when the dolerites were intruded.

Comparison with results from Europe. The pole positions calculated from the magnetic directions in rocks of the same age but from different continents should be the same; if they are not, relative land movement between the sampling areas must have occurred subsequently. It is therefore interesting to compare the pole position obtained from these dolerite sills with those obtained from rocks of similar age from other parts of the world. Only results from Europe are available at the present time and it has been found convenient previously (Creer, Irving and Runcorn (1954)) to plot these ancient pole positions in the northern hemisphere, but clearly there will be complementary poles in the southern hemisphere and these are given in Figure 5.

The pole with respect to Europe has not yet been obtained at all stages in the Mesozoic, but it seems fairly certain that, at the time during which the Tasmanian dolerite sills were intruded, the pole lay somewhere in the region of what is now the South Atlantic, and at least 50° from the pole given by these dolerites. This suggests that there has been considerable relative movement between Tasmania and Europe since this time.

It would be of the greatest interest to know the magnetic directions of the Mesozoic lavas and intrusions of Antarctica (intrusions into the Beacon Sst.), South America (Sao Bento Series), South Africa (Karoo), and India (Rajmahal traps) in order to compare them with the Tasmanian results. If the reassemblies of the southern continents proposed by Wegener (1924) and Du Toit (1937) are correct, then these formations, like the Tasmanian dolerites, should disclose corresponding geomagnetic latitudes, and it should be possible to test strictly the validity of these reconstructions. These measurements ought to provide a critical test for the hypothesis of continental drift.

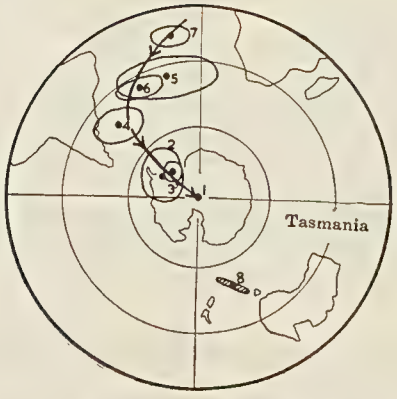


FIG. 5.—*Movement of the pole in the past.* The ancient positions of the pole are plotted on a Lambert's Azimuthal equal-area projection of the southern hemisphere. The oval regions represent the area within which the pole lay with a probability of 95 per cent. The shaded area numbered 8 is the probable pole position during the intrusion and cooling of the Tasmanian dolerites. The other poles are calculated from the results from Europe as follows:—1. Upper Tertiary and Pleistocene; 2. Oligocene; 3. Eocene; 4. Triassic; 5. Permian; 6. Devonian; 7. Cambrian.

6. Reversals of Magnetization.

In a bore-core studied by Jaeger and Joplin (1955), evidence was found of reversals of magnetization. The core is 1050 feet long and specimens from the upper half have north-seeking polarisations directed upwards (normal), and in the lower half pointing downwards opposed to the vertical component of the present Earth's field. It is argued that, if some sections had been inverted by mistake during transfer from the core barrel to the storage box, the reversed specimens would be distributed here and there all along the length of the bore-core. This is not so, the reversed specimens being confined with a few exceptions to the lower half, and it seems likely that a true reversal of direction is represented.

In the present work the pairs of specimens from 30 sites are all normally magnetized. The orientations by standard geological methods are not subject to the inversion errors as in bore-cores. If reversed magnetizations are a general characteristic of the dolerite sills such as would have arisen from reversals of the geomagnetic field during cooling, then they almost certainly would have been picked up in at least a few of these widespread sites. It seems rather likely that this bore-core reversal is due to some special Néel effect (Néel (1951)) by means of which the rock became magnetized during cooling in the opposite direction to the Earth's magnetic field. There are, however, two reasons why this cannot be regarded as evidence against the hypothesis of reversals of the geomagnetic field as proposed by Hospers (1954) who suggested

that reversals of the field in the Upper Tertiary and Pleistocene occurred every 25,000 to 250,000 years. Firstly, there is strong evidence that reversals with a comparable periodicity also occurred in the late Precambrian (Irving (1954)) and perhaps also in the Triassic (Clegg, Almond and Stubbs (1954)). In the intervening epochs, despite intensive study (Creer (1955)), reversals have not been recorded, and it is quite possible that they are confined to certain epochs, while at other times the geomagnetic field maintained a steady polarity. Secondly, it is possible that the time interval between reversals is longer than that required for the intrusion and cooling of the dolerite sills, and reversed magnetizations would not therefore be "fossilized".

TABLE III. *The Magnetic properties observed at* 30 *collection sites in the dolerite sills.*

Two samples have been obtained at each site and the results from a site are given as a means of these two.

ϕ declination in degrees east of geographic north.
θ dip in degrees away from the horizontal.
δ difference in degrees in direction between two samples from the same site.
I magnetic intensity per cc. *e.m.u.* $\times$ 10^{-4}.
K magnetic susceptibility, being the ratio of the intensity of magnetization in *e.m.u.* $\times$ 10^{-4} per cc. induced by an external field to the strength of that field, in this case 0·49 oersted.

TABLE III.

No.	Collection Locality	ϕ	θ	δ	I	K
1	Quarry near Derwent Park Road, Hobart	54	—77	22	3·3	4·2
2	Quarry near Park Street, Hobart	289	—76	4	16·3	22·4
3	Cutting on the road from Hobart to the aerodrome, near Bellerive	233	—75	7	41·5	3·9
4	Quarry at Little Oyster Cove near Kettering	55	—74	16	25·8	8·4
5	Small road cutting on Woodbridge-Gardiner's Bay Road, 2 miles west of Woodbridge ...	323	—78	29	0·6	1·4
6	Cutting on road from Cradoc to Huonville, 1 mile north of Cradoc	195	—85	7	3·0	4·1
7	Road cutting 1 mile south of site 8 on Huonville-Woodstock road	280	—70	2	10·5	7·3
8	Quarry on Huonville-Woodstock road 1 mile south-east of Huonville near bend in the Huon river	202	—81	15	6·4	3·5
9	Road cutting at Neika the summit of the Huon Highway 7 miles south-west of Hobart ...	289	—61	2	1·5	0·5
10	Quarry on the Lyell Highway 200 yards N.W. of Rosegarland Hotel near Gretna	293	—79	14	3·4	8·9

No.	Collection Locality	ϕ	θ	δ	I	K
11	Quarry on the Lyell Highway 2 miles east of Hamilton	275	—71	8	9·3	2·2
12	Quarry half way along the road between Ouse and Tarraleah	124	—78	12	68·1	27·7
13	Road cuttings near Tarraleah power station	241	—85	13	15·1	3·5
14	Cutting in mountain side for the pipes carrying water to Tungatinah power station	357	—84	12	30·8	1·9
15	Cuttings at Butler's Gorge just below the main dam	268	—82	17	3·5	4·6
16	Quarry 150 yards north of the camp at Butler's Gorge	8	—88	20	1·5	0·8
17	Quarry 200 yards north of the main dam at Butler's Gorge	97	—88	20	28·8	6·2
18	Quarry 3 miles north of Bronte	48	—84	6	8·1	2·9
19	Quarry ½ mile south of Kempton	322	—74	14	12·5	4·3
20	Quarry 2 miles north of Melton Mowbray	343	—73	15	24·6	16·0
21	Quarry near Bothwell	289	—77	26	41·8	6·8
22	Cuttings along the Liawenee canal	277	—85	7	33·6	6·6
23	Quarry near Latrobe	7	—81	23	4·6	3·8
24	Cataract Gorge quarry, Launceston	39	—83	6	21·9	12·4
25	Road cutting 1½ miles south-east of Murdunna on the Arthur Highway	357	—71	11	10·4	2·2
26	Road cutting 1 mile west of Orford on the Tasman Highway	25	—77	10	10·6	1·9
27	Road cutting near reservoir just north of Triabunna	15	—79	3	11·7	10·4
28	Road cutting on Tasman Highway 2 miles south of Swansea	68	—80	18	46·1	5·8
29	Road cutting east of the Swan river bridge, Cranbrook	13	—87	12	37·9	2·6
30	Road cutting on Tasman Highway between Bicheno and Cranbrook	123	—87	8	7·7	13·5

Acknowledgments

I wish to offer grateful acknowledgments to the following people: Professor J. C. Jaeger, of the Australian National University, who suggested the investigation and who read and criticised the manuscript; Professor S. W. Carey, of the University of Tasmania, who allowed me the use of the facilities of his Department, who arranged for me to use University vehicles during field-work, who provided information concerning the Cartwright Point breccia, and who gave me much encouragement; Professor S. W. Carey, Mr. M. R. Banks and Miss Edith Smith, of the University of Tasmania, who directed me to many of the exposures from which I was able to obtain suitable rock specimens.

Notes

(i) It was remarked on page 158 that there may have been epeirogenic tilting of about 5° to the south-west during the Tertiary. This would have the effect of changing the ancient pole co-ordinates given in Table II to Lat. 55° S., Long. 148° E.; the size of the error area is not appreciably altered.

(ii) Professor P. M. S. Blackett and Dr. J. A. Clegg, of Imperial College, London, have kindly communicated the results of their measurements on four vertical bore-cords. These, of course, give the dip only. The results are as follows: bore-hole No. 5001, 30 samples, average dip 86°; No. 5002, 7 samples, average dip 84°; No. 8102, 8 samples, average dip 86°; bore-hole No. 8103, 9 samples, average dip 86°. These confirm, within the errors, the mean dip value of 85° (Table II) obtained from surface samples.

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PARASITIC TURBELLARIA FROM TASMANIAN ECHINOIDEA

By

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(With nine Text Figures)

Abstract

A new Acoel turbellarian, *Avagina vivipara* n. sp., found in the oesphagus of the common heart-urchin, *Echinocardium cordatum* (Pennant) is described. Two new rhabdocoel turbellarians belonging to the family Umagillidae are also described. One occurs in the intestine of *Echinocardium cordatum* (Pennant) and has been named *Marcusella pallida* n. sp.; the other occurs in the intestine of the sea-urchins *Heliocidaris erythrogramma* (Valenciennes) and *Amblypneustes ovum* (Lamarck) and has been named *Syndesmis punicea* n. sp. A comparison of the new species with the known species in the genera is made. The Echinoids from which the parasites were taken were collected at Blackman's Bay and Ralph's Bay in the estuary of the River Derwent, Tasmania.

Introduction

Only seven species of Turbellaria appear to have been recorded as endoparasites of Echinoidea. They are as follows:—

(1) *Avagina incola* Leiper (1904) from the "accessory canal" of the heart-urchin, *Echinocardium cordatum* (Pennant) taken in the Firth of Clyde, Scotland. Also from the intestine of *Echinocardium flavescens* (O. F. Müller) and *Spatangus purpureus* O. F. Müller from Plymouth and the Scandinavian coast (Westblad 1949 and 1953).

(2) *Avagina glandulifera* Westblad (1953) from the intestine of *Spatangus purpureus* O. F. Müller at Plymouth.

(3) *Syndesmis echinorum* François (1886) from the intestine of *Strongylocentrotus lividus* (Lamarck) and *Echinus acutus* Lamarck in the Mediterranean; also from the coelom of *Echinus sphaera* O. F. Müller at Roscoff, France (Cuénot, 1892), from the intestine of *Sphaerechinus granularis* (Lamarck) at Naples (Russo, 1895), from the intestine and coelom of *Echinus esculentus* Linnaeus at Plymouth (Shipley, 1901) and the intestine of *Strongylocentrotus dröbachiensis* (O. F. Müller) at Alexandrowsk (von Graff, 1903).

(4) *Syndesmis antillarum* Stunkard and Corliss (1951) after Powers (1936) from the coelom of *Diadema antillarum* Philippi in the Gulf of Mexico.

(5) *Syndesmis franciscana* (Lehman, 1946) from the intestine of *Strongylocentrotus franciscanus* (A. Agassiz) at Monterey Peninsula, California.

(6) *Syndesmis dendrastorum* Stunkard and Corliss (1951) from *Dendraster excentricus* (Eschscholtz) from coast of California.

(7) *Marcusella atriovillosa* Westblad (1953) from the intestine of *Spatangus purpureus* O. F. Müller at Plymouth.

It will be noticed that of the species mentioned above *Syndesmis echinorum* François has been recorded from a number of different hosts and from widely separated localities. Stunkard and Corliss (1951) have already pointed out that the descriptions of this species given by different authorities do not always agree and that they may be dealing with more than one species.

Westblad (1953, p. 270) regards *Syndesmis antillarum* as identical with *Syndesmis franciscana* (Lehman).

In the present paper a new acoel and two new rhabdocoels are added to the list of endoparasitic turbellarians found in echinoids. They are described in the following pages.

Descriptions

Order: ARCHOOPHORA

Sub-order: ACOELA

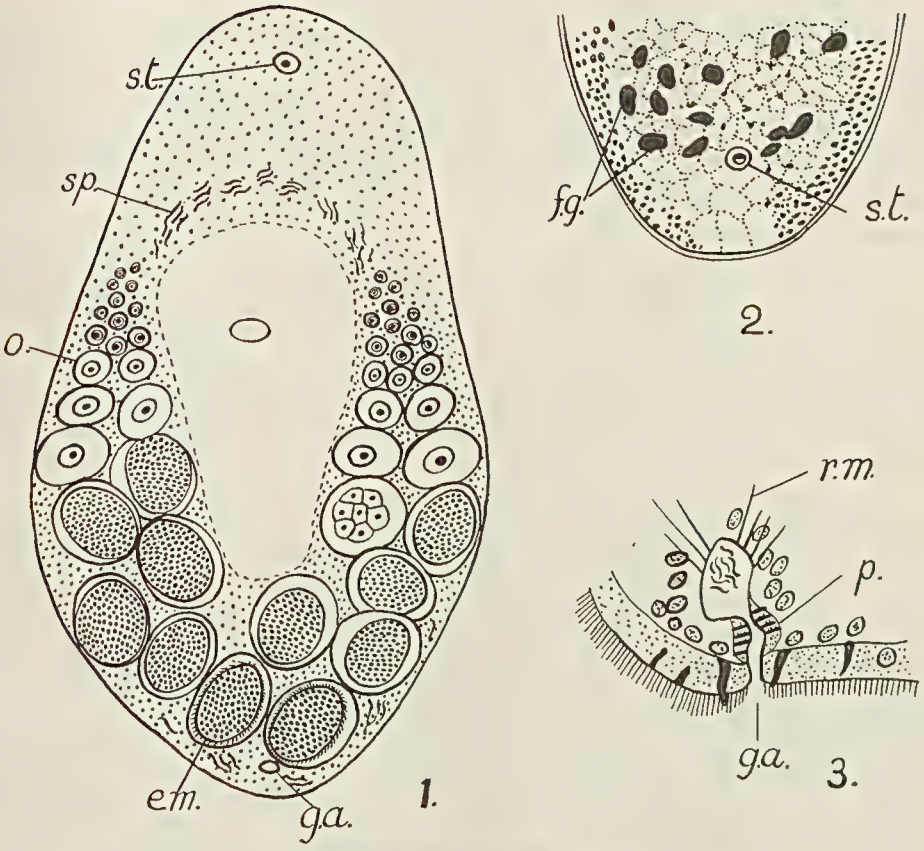
Genus: *Avagina* Leiper (1902), 1904

Avagina vivipara n. sp.

(TEXT FIGURES 1-3)

The body is white, translucent and completely covered with cilia. It is somewhat leaf-shaped, convex dorsally and flat or slightly concave ventrally. In fixed specimens there is a tendency for the posterior end to curve round ventrally. The length is 1·09-1·37 mm. and the width at the widest part, which is just behind the middle, is 0·62-0·64 mm. The mouth is ventral and median, situated in the anterior half about three-eighths of the body-length from the front. The male genital aperture is ventral and slightly in front of the posterior end. No female genital aperture is present. Frontal glands discharge through an opening at the anterior end. There are no eyes but the usual statocyst is situated about one-sixteenth of the body-length from the anterior end and can be seen through the translucent tissues of the living animal. In some specimens large developing embryos lodged in cavities in the parenchyma of the posterior third may also be seen through the body wall. In other specimens, which appear to be protandrous forms, no such embryos are visible.

The cilia covering the body are about 5 μ in length. They arise from a thin basal layer that has the appearance of a cuticle. Below this layer is the epithelium which is about 6 μ in thickness. Cell walls are more distinct and nuclei more numerous in the epithelium of the ventral surface than in that of the dorsal surface. A few scattered epithelial gland cells are present.



Avagina vivipara n. sp.

FIG. 1.—General organization of animal.
FIG. 2.—Frontal section of anterior end showing frontal glands.
FIG. 3.—Sagittal section through genital aperture.

Below the epithelium are the usual transverse, oblique and longitudinal muscle layers. In the cortical region of the parenchyma, immediately below the muscle layers, numerous nuclei and cells rich in cytoplasm are present. In the medullary region the cells are larger, the nuclei less numerous and large vacuoles are evident. In the posterior third of the animal the vacuoles become extremely large. Anteriorly large glands, which discharge through the frontal aperture are present. These glands are in the form of rounded masses which stain deeply with haematoxylin and which are lodged mainly in the parenchyma of the anterior quarter. Between the front of the body and the digestive tract, the parenchyma is traversed by a number of longitudinal and dorso-ventral muscles. Long oblique fibres, which function as frontal retractors, extend from the front of the body posteriorly and are inserted in the body-wall almost half way from the front.

The digestive region lies in the middle half of the animal. It is delimited by numerous nuclei and cells rich in cytoplasm, as well as by longitudinal muscle fibres. Its length measures about 0·5 mm. and its diameter at the widest part, which is above the mouth, measures 0·26 mm. The digestive region normally consists of a cellular reticulum containing diatoms and other food particles but owing to the fact that the animals often disgorge the reticulum and its contents during fixation, the digestive region sometimes appears as an empty space in the parenchyma. The mouth opens directly into the digestive reticulum, no pharynx being present.

The brain consists of two widely separated ganglia and gives rise to the usual longitudinal nerves, namely, two dorsal, two ventral and two lateral. The statocyst lies in close contact with the brain and is about 79 μ from the front and 69 μ above the ventral surface. In the resting condition it is spherical measuring 21 μ in diameter. It encloses a spherical statolith, 10 μ in diameter. Under the action of haematoxylin one-half of the statolith becomes deeply stained, while the other half remains unstained in fixed material.

The ovaries are paired and lie one on each side of the body in the middle third. They do not unite posteriorly. The anterior oocytes are small. They arise in the parenchyma on each side of the front part of the digestive region. There is a gradual increase in size of the oocytes posteriorly. Mature ova occur slightly behind the middle of the body. They measure 108 μ by 89 μ and have a nucleus measuring 47 μ by 39 μ. Behind the mature ova the parenchyma of the body contains large vacuoles or cavities, which measure about 130 μ by 120 μ. These cavities enclose developing embryos, each of which is surrounded by a delicate membrane. Only one embryo occupies a cavity. Those immediately behind the ovaries are usually at an early stage of development, whilst those in the more posterior cavities are frequently well advanced and ready to leave the parent. These well advanced embryos measure about 111 μ long and 84 μ wide. They have a ciliated epithelium, statocyst, frontal glands, and musculature. The maximum number of embryos in one individual appears to be twelve. Whilst examining gravid specimens of the turbellarian in sea-water, embryos were observed to escape from the parent by rupture of the body wall. No vagina or other accessory female organs are present.

The testes are diffuse. They occur in front of the digestive region and also dorso-laterally. Spermatozoa at various stages of formation occur in individuals carrying mature ova and embryos, but are more abundant in individuals which appear to be protandrous hermaphrodites. In the latter the ovaries are very small with immature oocytes. The diffuse testes, however, are strongly developed and, although no male ducts are present, a trail of spermatozoa can be traced extending through the parenchyma on each side from in front of the digestive region to the posterior end of the body. In both gravid and protandrous individuals the spermatozoa enter a vesicula seminalis, which has the form of a pyriform sac about 63 μ long and 26 μ in diameter. The narrow ventral end of the vesicle opens at the genital aperture, which is about 60 μ in front of the posterior end of the body. Weak circular

muscles surround the narrow part of the vesicle and it is provided with retractor muscles which pass upwards through the parenchyma. It seems probable therefore that the narrow neck of the vesicle can be slightly everted to form a penis. This, however, has not been observed.

HABITAT: *Avagina vivipara* n. sp. occurs in the oesophagus of the common heart-urchin, *Echinocardium cordatum* (Pennant), and is usually found a short distance inside the mouth. It does not occur in other parts of the alimentary canal. Of 68 heart-urchins examined 18 were found to contain the parasite. Usually only two or three specimens of the turbellarian are found in the one host, the greatest number present in a single heart-urchin being five.

LOCALITY: The heart-urchins containing the parasite were taken by dredging in Ralph's Bay, Derwent Estuary, August, 1955.

AFFINITIES: *Avagina vivipara* n. sp. is closely related to *A. incola* Leiper and *A. glandulifera* Westblad but differs from them in the position of the male genital aperture, in the ovaries not being united posteriorly and in its viviparous habit.

Order: NEOOPHORA

Sub-order: NEORHABDOCOELA

Family: *Umagillidae* Wahl, 1910

Genus: *Marcusella* Westblad, 1953

Marcusella pallida n. sp.

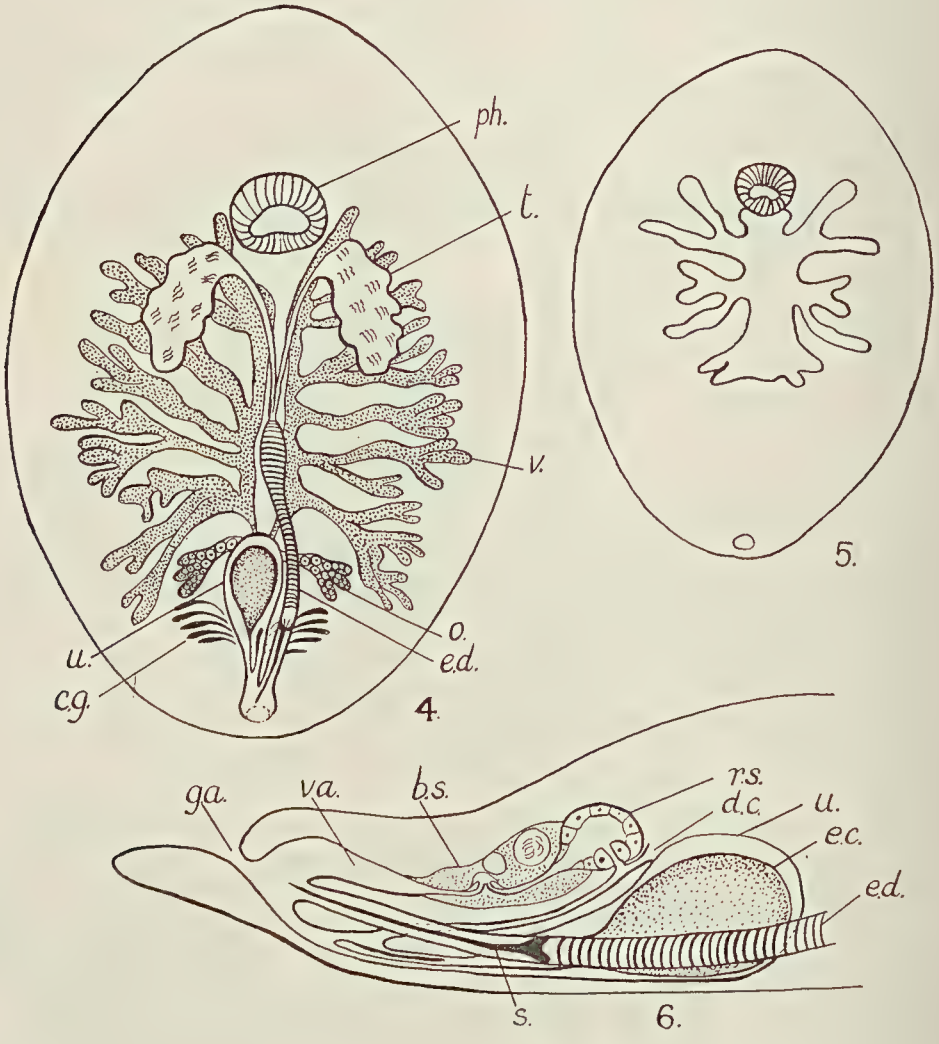
(TEXT FIGURES 4-6)

The turbellarian is grey and translucent in appearance. It is broadly leaf-shaped to almost circular in outline. After fixation specimens measure 1·3-1·7 mm. in length and 0·8-1·16 mm. in width at the widest part. The dorsal surface is slightly convex, the ventral surface flat or concave. The body is very thin dorso-ventrally at the margin. Dorsal and ventral surfaces are completely ciliated. The mouth is ventral and about one-third of the body-length from the front. The genital aperture is dorsal and almost at the posterior end of the body.

The dorsal epithelium is about 5 μ and the ventral epithelium about 3 μ in thickness. The cilia of the dorsal surface are slightly shorter than those of the ventral surface. The subdermal muscular sheath is composed of the usual layers, the transverse fibres being fine and very numerous. The diagonal and longitudinal fibres are much stronger and less numerous. The body parenchyma is composed of large cells, which in transverse sections appear as a loose reticulum with little cytoplasm and few nuclei.

The mouth leads into a pharynx doliiformis which projects downwards and forwards from the oesophagus. The pharynx measures about 0·14 mm. in diameter and 0·16 mm. in length. Its lumen is about 52 μ wide and is lined by the extension of the long necks of the oesophageal gland cells. The oesophagus measures about 65 μ long and 105 μ in diameter. It is surrounded by the usual glands. The intestine is short, its length in the mid-line being about 0·328 mm. It lies in the middle third of the body and gives off four pairs of lateral diverticula, which are often only clearly seen when they contain food. The anterior pair extend forwards on each side of the pharynx. The lumen of the intestine contains numerous isolated cells enclosing food particles. These cells appear to have

become detached from the intestinal wall. In some cases the lumen of the intestine and that of the diverticula is obliterated by cells. Parts of the diverticula become separated from the main part of the intestine and form cavities which lie in the parenchyma and often contain food.



Marcusella pallida n. sp.

FIG. 4.—Ventral view of general organization of animal.
FIG. 5.—Showing the form of the intestine.
FIG. 6.—Lateral view of end organs of reproductive system.

The testes are paired, compact and slightly lobed organs measuring about 197 μ long and 90 μ wide. They are situated one on each side in the anterior part of the middle third of the animal. In specimens that are not fully extended they may be level with the pharynx. The vasa deferentia arise from the anterior ends of the testes and on the inner side. They are short and pass obliquely backwards, converging and uniting at the anterior end of the ejaculatory duct (common sperm duct). They lead into the ejaculatory duct through a common aperture surrounded by a sphincter muscle. The anterior end of the ejaculatory duct is slightly enlarged to form a seminal vesicle, which is 21 μ-26 μ in diameter, the greater part of the duct being 16 μ in diameter. The position of the seminal vesicle depends on the degree of extension of the animal and the degree of extrusion of the stylet. In contracted specimens it may lie close behind the pharynx. In extended specimens it usually lies below the posterior half of the intestine or just in front of the uterus. The ejaculatory duct passes posteriorly at the left of the uterus. Here it may or may not form a loop. The wall of the duct is provided with strong bands of circular muscles and also with longitudinal muscles. Posteriorly the duct ends in a cuticular stylet, which lies in the antrum masculinum. The stylet measures 134 μ-137 μ long and is about one-tenth the length of the animal. At its junction with the ejaculatory duct its base forms a strongly cuticularized ring, into which the longitudinal muscles of the duct are inserted. The base of the stylet measures 18 μ in diameter. From the base the stylet gradually tapers to a fine point. The antrum masculinum is about 110 μ long and 16 μ in diameter. It opens into the atrium genitale immediately below the vaginal aperture.

The vitellaria are paired and dendritic, forming four or five pairs of main branches, which divide to give rise to secondary and tertiary branches. The anterior branches extend on either side of the pharynx and the posterior branches slightly beyond the lobes of the ovaries. There is a marginal zone into which the vitellaria do not penetrate.

The ovaries are paired and lie between the bulbous part of the uterus and the posterior branches of the vitellaria. Each ovary gives rise distally to two or three small lobes. The number of lobes is variable. The ovaries and vitellaria open close together into the anterior end of the ductus communis (ovovitelline duct) at a position above the anterior end of the uterus.

The uterus is short and lies in the posterior third of the body. It occupies a median position close to the ventral surface and extends from the vitellaria to the antrum femininum. Including the latter its total length measures 368 μ-458 μ. The anterior bulbous part of the uterus is 157 μ-236 μ long and about 118 μ in width. The wall is 13 μ in thickness. The narrow neck of the uterus is about 34 μ in diameter. Only a single egg capsule is contained in the uterus. It is yellow and pyriform with a short polar filament at one end. The free end of the filament is bent back in the neck of the uterus and is thickened by secretion from the cement glands. The bulb of the capsule is 184 μ long and 94 μ wide. The polar filament is 197 μ in length.

The vagina leads forward from the upper part of the genital atrium and is about 131 μ in length. Posteriorly it has a diameter of about 30 μ and is lined with long slender cells. As it extends forwards it gradually narrows to form a cuticularized bursal canal, which enters the bursa seminalis posteriorly and for the whole of its length is contained within the bursa. Near the centre of the latter it ends in a cuticular dome-shaped structure similar to that described and figured by Lehman (1946) for *Syndesmis franciscana*, and which he designates as the bursal valve.

The bursa seminalis is a fusiform structure about 132 μ long and 60 μ in diameter at its widest part. It is bounded by a membranous wall and seems to consist of a syncytium containing a few nuclei and a number of vacuoles. The latter usually contain spermatozoa. The anterior end of the bursa is on the left of the receptaculum seminis. The latter indents the right side of the bursa and communicates with it by a short cuticularized canal, which enters the bursa laterally and terminates in the bursal valve immediately in front of the termination of the bursal canal from the vagina. The receptaculum seminis is pyriform when slightly extended and measures 121 μ long and 66 μ in diameter at its widest part. The lumen of the bulbous anterior portion of the receptacle is 31 μ in diameter and bounded by a wall of large cells with granular cytoplasm. The wall is 13-15 μ in thickness. Given off antero-ventrally from the receptacle is a very short duct which opens into the dorsal side of the ductus communis immediately behind the openings of the ovaries. As in other Umagillidae the ventral aperture of the receptacle is surrounded by very large gland cells.

The ductus communis (ovovitelline duct) lies between the uterus and the receptaculum seminis. It originates immediately behind the vitellaria and above the bulbous part of the uterus. It passes posteriorly to open by a wide aperture into the dorsal side of the neck of the uterus at a distance of about 65 μ from the genital atrium. Here also the accessory glands of the ductus communis open into it immediately before it joins the uterus.

The antrum femininum extends from the junction of the ductus communis and uterus to the genital atrium. It measures about 65 μ in length and 42 μ in diameter. Close behind the aperture of the ductus communis the antrium femininum receives the ducts of the cement glands. These glands are situated on either side in the posterior part of the body immediately behind the ovaries. They are not very strongly developed. The antrum femininum, antrum masculinum and the vagina are lined with cells having a frayed-out appearance. Similar cells line the genital atrium. The latter cavity is of the usual form. Its wall is provided with circular and longitudinal muscles. Retractor fibres extend from it to the body wall. It opens dorsally at the genital aperture immediately in front of the posterior end of the body. There is no vestibulum atrii.

HABITAT: *Marcusella pallida* n. sp. occurs in the second spiral of the alimentary canal, that is in the intestine of the common heart-urchin, *Echinocardium cordatum* (Pennant). The turbellarian is not very common.

Sixty-eight heart-urchins were examined and only ten found to be infected. These yielded eleven specimens of the parasite, the maximum number found in one host being four.

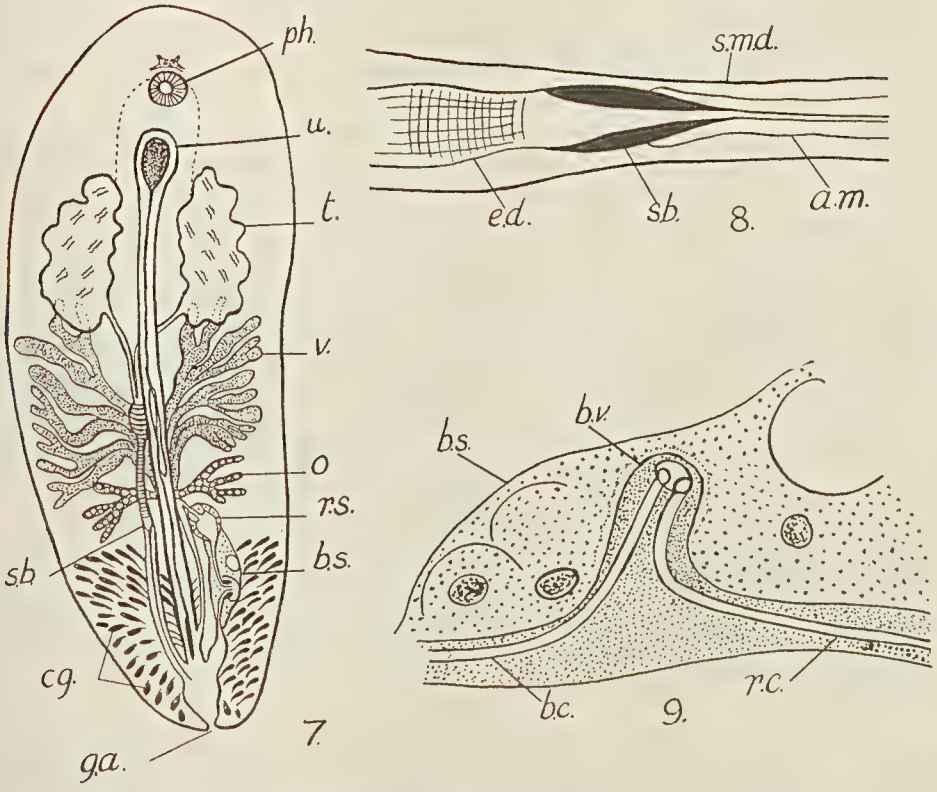
LOCALITY: The heart-urchins from which the turbellarians were obtained were collected by dredging in Ralph's Bay, the Derwent Estuary, during August, 1955.

AFFINITIES: *Marcusella pallida* n. sp. resembles the only other recorded species, *Marcusella atriovillosa* Westblad, in having a short uterus, small testes, short vasa deferentia, a long ejaculatory duct and a short stylet. It differs from that species in the form of the intestine and ovaries and in the extent of the vitellaria.

Genus: *Syndesmis* Silliman, 1881

Syndesmis punicea n. sp.

(TEXT FIGURES 7-9)



Syndesmis punicea n. sp.

FIG. 7.—General organization of animal.
FIG. 8.—Longitudinal section through base of stylet and adjacent structures.
FIG. 9.—Longitudinal section through part of bursa seminalis and bursal valve.

Living specimens of this turbellarian are orange red in colour. The long intestine shows through the translucent body-wall as a median yellow tube. The vitellaria appear pink. The body is somewhat leaf-shape in outline, being broadly rounded in front and pointed posteriorly. The dorsal surface is convex and the ventral surface usually flat. The length of mature specimens carrying an egg capsule varies from 2·0 mm. to 4·7 mm. and the width at the widest part of the body from 1·2 mm. to 2·4 mm. In the following description all measurements, unless otherwise stated, are based on an extended specimen having a length of 3·4 mm.

Dorsal and ventral surfaces of the body are completely ciliated. The cells forming the dorsal epithelium are about 15 μ in height. Their cytoplasm is finely granular and their oval nuclei measure 8 μ by 6 μ. A few pyriform gland cells open on the dorsal surface. The cells of the ventral epithelium are about 5 μ in height and their nuclei measure 6 μ by 3 μ. The cilia of both upper and lower surfaces are about 3 μ in length. A delicate basement membrane underlies the epithelia. The usual dermal musculature consisting of transverse, oblique and longitudinal fibres forms a sheath round the body below the basement membrane.

The brain is situated immediately in front of the pharynx and about 18 μ above the ventral surface. Numerous ganglion cells are present. Their nuclei are oval and measure 10 μ by 8 μ.

The mouth is ventral and median, situated about one-tenth of the body-length from the front. It opens into a small prepharynx which leads into a typical pharynx doliiformis measuring 0·15 mm. long in its dorso-ventral axis and 0·16 mm. in diameter. The usual muscles are present, the inner circular fibres and radial fibres being strongly developed, whilst the outer circular fibres and the inner and outer longitudinal fibres are much weaker. A well developed basement membrane surrounds the pharynx. Radially arranged protractor muscles extend from the sides of the pharynx to the basement membrane of the ventral epithelium. Somewhat weaker retractor muscles extend from the sides of the pharynx to the dorsal epithelium. Between the pharynx and the intestine is a short oesophagus, which is surrounded by a mass of elongate pyriform gland cells. The long necks of these cells extend downwards into the lumen of the pharynx and form the lining of the latter.

The intestine, which lies in the mid-line close below the dorsal surface, extends from the oesophagus to the genital atrium. It is a straight tube without diverticula and has a transverse diameter of about 0·28 mm. and a length about three-quarters that of the animal. It is surrounded by a fibro-muscular sheath and its lumen is lined by long club-shaped cells, the cytoplasm of which contains numerous vacuoles enclosing ingested food particles. The vacuoles measure up to 32 μ in diameter.

The testes are paired and lobed. They lie one on each side in the anterior half of the body. In some specimens they are behind the level of the pharynx, in others they extend forwards so that their anterior ends lie at the sides of the pharynx. Each is about 0·7 mm. long and 0·4 mm. wide. They are separated from the parenchyma by a fibrous investment. Each lobe is divided into a series of compartments, which contain spermatozoa at various stages of development. The vasa deferentia leave the testes on the inner side and near the posterior end of the gonad.

In well extended specimens the two ducts converge and lie side by side at the right of the uterus. They pass posteriorly and near the centre of the body they unite and enter the anterior end of the ejaculatory duct, which enlarges slightly to form a seminal vesicle. The diameter of the vesicle is about 34 μ and the length 92 μ. The vesicle lies almost below the middle of the intestine. The ejaculatory duct passes posteriorly at the right side of the uterus. Its diameter is about 26 μ and its length including the seminal vesicle is about 0·85 mm. At its posterior end it opens into the base of the hollow stylet usually below the middle of the bursa or receptaculum seminis. The stylet measures 0·668 mm. long and is about one-fifth the length of the animal. The base of the stylet is rather narrow and elongated, differing in this respect from the usual wide ring-like base of other species. The diameter of the base is about 18 μ. The rest of the stylet is a very fine cuticularized tube extending the full length of the antrum masculinum.

The vitellaria are dendritic and lie mainly in the middle third of the body. There are four or five primary branches on each side. Some of the anterior branches overlap the posterior part of the testes. The left and right vitellaria converge and open into the anterior end of the ductus communis at about one-third of the body length from the posterior end.

The ovaries are paired and lie immediately behind the vitellaria. Each is produced into four or five finger-like lobes. The two ovaries open laterally into the ductus communis immediately behind the openings of the vitellaria. The largest ova in the ovary are about 39 μ in diameter and their nuclei about 18 μ in diameter.

The uterus is medio-ventral in position. Its total length including the antrum femininum is 2·27 mm. The anterior bulbous part is near the pharynx and measures 223 μ long and 137 μ in diameter. The neck of the uterus is about 53 μ in dorso-ventral diameter. A single yellow egg capsule is contained in the uterus. It is pyriform and produced at one end into a long slender polar filament, which is coiled up in the neck of the uterus. The bulbous part of the capsule is 210 μ long and 131 μ in diameter. Its wall is about 13 μ thick.

The vagina passes forwards from the dorsal part of the genital atrium. It lies immediately below the posterior part of the intestine. Posteriorly it is a wide tube with a lining of long slender cells resembling those lining the genital atrium. After proceeding forward for a distance of about 158 μ it narrows and its wall becomes cuticularized forming a tube about 3 μ in diameter. This tube enters the bursa seminalis postero-ventrally and terminates in a cuticularized bursal valve as in the preceding species.

In extended specimens the bursa is more or less spindle shaped and measures 0·524 mm. long and 0·105 mm. in diameter. In contracted specimens it is indented in front by the receptaculum seminis. The wall of the bursa has a fibrous appearance. It encloses a protoplasmic syncytium in which there are large vacuoles, some of which contain spermatozoa. Arising in the bursal valve, and close in front of the end of the bursal canal from the vagina, is a shorter cuticularized duct, which passes

downwards and forwards into the receptaculum seminis. The latter organ when extended is pyriform and elongate but when contracted it is almost spherical. Antero-ventrally it opens by a short duct into the dorsal side of the ductus communis immediately above the junction of the latter with the ovaries. The aperture leading from the receptaculum is surrounded by the usual large gland cells. When extended the receptaculum is 0·784 mm. long and 79 μ in diameter at its widest part.

The ductus communis (ovovitelline duct) passes posteriorly between the receptaculum seminis and the neck of the uterus. Below the posterior end of the bursa the ductus communis opens into the dorsal side of the neck of the uterus. Just before so doing it receives the ducts of the accessory glands.

The antrum femininum, which extends from the posterior end of the ductus communis to the atrium as a continuation of the uterus, is perforated by the numerous ducts from the cement glands. The genital atrium measures about 158 μ long and 105 μ in diameter. It is lined with the usual long slender cells. The wall is furnished with circular and longitudinal muscles as in other species. The atrium opens to the exterior by the genital aperture situated at the posterior end of the body.

HABITAT: *Syndesmis punicea* n. sp. occurs in the intestine of the sea-urchins *Heliocidaris erythrogramma* (Valenciennes) and *Amblypneustes ovum* (Lamarck). The turbellarian was present in seven out of nine specimens of *H. erythrogramma* and in five out of five specimens of *A. ovum* examined. The largest number found in a single specimen of *H. erythrogramma* was eighteen and in *A. ovum* forty-five.

LOCALITY: Infected specimens of *H. erythrogramma* were collected at Blackman's Bay and Ralph's Bay during April and August, 1955. Infected specimens of *A. ovum* were dredged at Ralph's Bay during August, 1955.

AFFINITIES: The relationship of *Syndesmis punicea* n. sp. to other members of the genus is shown in the following key to the species:—

1. Uterus extends into anterior half of body 2
   Uterus does not extend into anterior half of body ....
   S. dendrastrorum Stunkard & Corliss.
2. Ejaculatory duct with several coils .... *S. echinorum François.*
   Ejaculatory duct with one or no coils 3
3. Stylet about one-third body length 4
   Stylet about one-fifth body length .... *S. punicea* n. sp.
4. Base of stylet near middle of body ....
   S. antillarum Stunkard and Corliss.
   Base of stylet below receptaculum seminis ....
   S. franciscana (Lehman).

In connection with the above key it should be mentioned that the distinction between *S. antillarum* and *S. franciscana* is based on the figures given by Powers (1936, p. 319) and Lehman (1946, p. 300). Westblad (1953) regards the two species as identical.

Acknowledgments

My thanks are due to Mr. A. M. Olsen and Mr. J. Dowsett of the Fisheries Division, C.S.I.R.O., for assistance in collecting *Holocidaris erythrogramma* at Blackman's Bay. I am also indebted to Mr. J. L. Hickman and Mr. D. Alexander of the Zoology Department of the University of Tasmania for help in obtaining other Echinoidea.

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Abbreviations Used in Text Figures

a.m.—Antrum masculinum
b.c.—Bursal canal
b.s.—Bursa seminalis
b.v.—Bursal valve
c.g.—Cement glands
d.c.—Ductus communis
e.c.—Egg capsule
e.d.—Ejaculatory duct
e.m.—Embryo
f.g.—Frontal glands
g.a.—Genital aperture
O.—Ovary
p.—Penis
r.c.—Canal from bursa to receptaculum seminis
r.m.—Retractor muscle
r.s.—Receptaculum seminis
s.—Stylet
s.b.—Stylet base
sp.—Spermatozoa
st.—Statocyst
s.m.d.—Sheath of male duct
t.—Testis
u.—Uterus
v.—Vitellaria
va.—Vagina

NOTES ON MARINE ALGAE FROM TASMANIA

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(With Three Plates)

Abstract

Notes are given on ten species of marine algae from Tasmania, seven of them being new records for the State.

Introduction

Since the time of Harvey there has been, with the exception of the work of Lucas, very little attention paid to the rich marine algal flora of Tasmania. The list of Tasmanian marine algae published by Lucas (1928) has recently been brought up to date by Guiler (1952) with a check list in which the synonymy of the earlier list is revised and new records added to make a total of approximately 546 species. Levring (1953) has added several species to the list, but it seems certain that a considerable number of species occurring in the area, particularly the smaller forms, are yet to be recorded.

Species marked * are recorded for the first time from Tasmania.

Division Cyanophyta

Hormogonales—Rivulariaceae

* *Rivularia firma* Womersley 1946, Stud. mar. alg. southern Aust. Introd. and No. 1, p. 130, fig. 2 *a-b*.

This species is characterised by its very firm solid thallus and abundant intercalary heterocysts.

Hab.: A single drift specimen, mouth of Currie River, north coast of Tasmania, 17. ix. 1950—Cribb.

Extra-Tasmanian distrib.: Kangaroo Is., South Australia.

Division Chlorophyta

Chaetophorales

* *Sporocladopsis novae-zelandiae* Chapman 1949. Some new Species and Forms of Mar. Alg. N.Z. p. 496, fig. 4. *Pl. 1, fig. 1-6; pl. 2, fig. 3.*

Forming green or yellow-green colonies up to 10 mm. diam., round, irregular or ring-shaped, sometimes of up to 3 concentric rings; basally of a single layer of densely placed prostrate filaments of cylindrical or irregular cells, 5-18 μ $\times$ 5-10 μ; almost every cell of the prostrate

system bearing an erect branch which may be many-celled, or short and capped with a terminal sporangium; erect filaments unbranched, often approx. 600 μ long, sometimes up to 1,050 μ, 7-11 μ diam. in lower and mid parts, sometimes tapering to 5-6 μ near apex; cells cylindrical or slightly barrel-shaped, usually 1-3 diam. long, sometimes up to 5-6 diam. long near apex; chloroplast single, parietal, encircling the protoplast; sporangia borne on erect filaments, alternate or somewhat secund, generally 1 to a cell or exceptionally 2 from the same cell, ellipsoid or ellipsoid-pyriform, often narrowed unevenly at the base, 11-14 μ broad, 17-21 μ long, dehiscing by a terminal pore; a new sporangium sometimes proliferating within the wall of a discharged sporangium; occasionally a cell of an erect filament enlarging to form an intercalary sporangium; sporangia also sessile on the prostrate filament or terminal on a 1-celled stalk, sometimes with a second sporangium born to one side of the upper end of the supporting cell.

There is no penetration of the host tissue by the epiphyte, but beneath each colony the host frequently develops a thickened laminated cuticle appearing somewhat cork-like, often 10-14 μ thick, but occasionally up to 35 μ thick.

Hab.: On *Sarcophycus potatorum* (Labill.) Kuetz., Port Arthur, 8. ii. 1951, 31. iii. 1951, 7. ii. 1952.

Extra-Tasmanian distr.; New Zealand, epiphytic on *Pachymenia* and *Carpophyllum*.

SIPHONALES—Codiaceae

* *Rhipiliopsis peltata* (J. Ag.) A. & E. S. Gepp 1911, Codiaceae Siboga Exped. p. 45, figs. 118-122; Womersley 1950, Mar. Alg. Kangaroo Is. III, p. 146. *Pl. 2, fig. 4.*

The green peltate frond up to 3 cm. diam. is borne on a very short and frequently excentric stipe.

This appears to be a rare species and apart from the type collection of J. B. Wilson from Port Phillip Heads, Victoria, the only collections recorded are those of Womersley (1950) from shaded rear littoral pool and deeper pools of the sub-littoral fringe at Kangaroo Island.

Hab.: Dredged at 22 fathoms, five miles south of Goose Island, 5. xi. 1951—A. M. Olsen.

Extra-Tasmanian distr.: Victoria, Kangaroo Is.

Division PHAEOPHYTA

ECTOCARPALES—*Ectocarpaceae*

* *Ectocarpus mitchellae* Harvey 1852, Nereis Boreali—Americana Pt. 1. p. 142, pl. 12, fig. G; Boergesen 1941, Some Mar. Alg. from Mauritius Pt. 2, p. 7, fig. 1-5. *Pl. 2, fig. 1.*

Occurring in dense tufts up to 8 cm. tall; chromatophores disc-shaped; plurilocular sporangia up to 105 μ long, obtuse, ellipsoid to cylindrical or sometimes ovoid-ellipsoid.

Hab.: On *Hormosira banksii* (Turn.) Dcne., Port Arthur, 16. x. 1951—Cribb.

Extra-Tasmanian distr.: Very widely distributed.

* *Ectocarpus globifera* Kuetzing 1843, Phyc. gen., p. 289; Boergesen 1926, Mar. Alg. Canary Is. II, p. 48, fig. 25-26. *Pl. 3, fig. 3.*

Filaments up to 52 μ diam.; chromatophores disc-shaped; sporangia ovoid or ovoid-ellipsoid, up to 80 μ broad and 105 μ long, on a pedicel of a single cell, borne singly or in opposite pairs on main axis and its branches.

Hab.: On *Ecklonia radiata* (Ag.) J. Ag., Port Arthur, 31. iii. 1950—Cribb.

Extra-Tasmanian distr.: Europe, Canary Is.

* *Ectocarpus granulosus* (Smith) C. Agardh 1828, Sp. Alg. 2 (1), p. 45; Taylor 1937, Mar. Alg. N.E. coast N. Amer. p. 113, pl. 7, fig. 7-9; Smith 1944, Mar. Alg. Monterey Pen., p. 81, pl. 11, fig. 1-2. *Pl. 3, figs. 1-2.*

Main filaments up to 70 μ diam.; cells in the larger branches $\frac{1}{2}$–$1\frac{1}{4}$ diam. long, often somewhat barrel-shaped; branching of main filaments opposite or alternate, in the lateral branches usually secund; chromatophores discoid; plurilocular sporangia ovoid and asymmetrical, up to 52 μ broad and 70 μ long, sessile and borne secundly on lateral branches.

Hab.: On *Ecklonia radiata* (Ag.) J. Ag., Port Arthur, 31. iii. 1950—Cribb.

Extra-Tasmanian distr.: Europe, Atlantic and Pacific North America.

SPOROCHNALES—Sporochnaceae

Sporochnus apodus Harvey 1860, " Algae " in Hooker—Flora Tasmanica, p. 287; 1859, Phycol. Aust. 2, pl. 92. *Pl. 2, fig. 2.*

The sessile nature of the receptacle distinguishes this species from all others of the genus. The larger of the specimens here recorded was approximately 18 inches long but lacked its base.

This species was described by Harvey on a single drift specimen from Georgetown, Tasmania, and there appears to be no record of the species having been found again until the collections here recorded were made.

Hab.: Dredged at Pittwater, 15. xi. 1950, 12. xii. 1951—A. M. Olsen.

Division RHODOPHYTA

NEMALIONALES—Acrochaetiaceae

Acrochaetium polyrhizum (Harv.) J. Agardh 1892, Anal. alg., p. 48; Levring 1953, Mar. Alg. Aust. I, p. 481, fig. 14-15 A-C; *Callithamnion polyrhizum* Harvey 1863, Phyc. Aust. 5, p. lvi.

Forming a dense red fringe 3-8 mm. long over host; sinuate endophytic filaments 15-20 μ diam. penetrating between utricles of host; erect

filaments densely branched, irregularly alternate or sometimes somewhat secund in the upper parts; cells of erect filaments 15-24 μ diam., 1-3 or more rarely 4 diam. long; branches tapering gradually or sometimes hardly at all to obtuse apices; chromatophore a parietal lobed plate with 1-2 pyrenoids; monosporangia 14-21 μ diam., 20-35 μ long, obovoid, ellipsoid-obovoid or ellipsoid, borne secundly on the inner sides of lateral branches near their base, occasionally sessile but usually on a short unicellular pedicel, sometimes one at the apex and another at the side, or more rarely the pedicel 2-celled with the lower cell also bearing a sporangium.

A. polyrhizum (Harv.) J. Ag., *A. grande* (Levring) J. de Toni and *A. codicola* Boergesen are all large species which have been described as epiphytes on *Codium*. Levring (1953), in recording both *A. grande* and *A. polyrhizum* from the southern part of Australia, remarks on the similarity between these two species, but apart from slight differences in size the only essential distinction which he makes is that in *A. grande* the cells are 3-5 diam. long and contain 1-2 (—4) pyrenoids while in *A. polyrhizum* they are 1·5-2·5 diam. long and contain one or occasionally more pyrenoids. Material from Port Arthur on which the present record is based has cells typically 1·5-3 diam. long but sometimes up to 4 diam., and with 1-2 pyrenoids. In the type description of *A. polyrhizum* Harvey gives the cell length as 2-4 diam.

A. codicola Boergesen (1927) is described from the Canary Islands and appears to agree very closely with the above species, and particularly with *A. grande* in having cells apparently 2-5 diam. long and with 1-5 or more pyrenoids. The chromatophore in young cells is a parietal lobed plate as in the other two species, but in older cells may become divided into 2 or more ribbon-like lobed discs.

There appears to be no essential difference in the branching or in the shape, size and distribution of sporangia in the three species.

In view of the small and somewhat inconstant nature of the differences between the three species, it seems doubtful whether they can be kept separate, though, as no material of *A. grande* and *A. codicola* is available to the author, no definite opinion can be expressed.

Hab.: On *Codium fragile* (Sur.) Heriot, lower littoral and sublittoral fringe, Port Arthur, 23. ix. 1950—Cribb.
Extra-Tasmanian distrib.: Victoria.

Chaetangiaceae

Chaetangium fastigiatum (Bory) J. Agardh 1852, Sp., gen. et ord. alg. 2 (2), p. 460; Levring 1953, Mar. alg. Aust., p. 512; *Chaetangium lingula* Harvey 1860, *in* Hooker, Flora Tas. II, p. 316.

Plants from Port Arthur are typically more or less lanceolate, up to 2·5 cm. high, simple or exceptionally once forked. They correspond well with the description of *C. lingula* but Levring (1953) is of the opinion that this species cannot be separated from *C. fastigiata* which has previously been known as a repeatedly forked species.

Hab.: Mid littoral, Port Arthur, 7. ii. 1952—Cribb.
Extra-Tasmanian distrib.: Fuegia, Falkland Is., Crotzet, Kerguelen, Auckland Is., Campbell Is., New Zealand, W. Aust.

CERAMIALES—Delesseriaceae

* *Platysiphonia miniata* (Ag.) Boergesen 1931B, Sur *Platysiphonia* nov. gen. . . . pp. 1-9, fig. 1-5; 1931A, Some Ind. Rhodoph. p. 20, fig. 13 (as *Sarcomenia miniata* (Ag.) J. Ag.). *Pl. 2, fig. 5.*

Tufts up to 4 cm. high; basal rounded filaments up to 225 μ diam.; flattened erect filaments up to 135 μ broad; cystocarps and stichidia both common.

Hab.: Shallow lower littoral pools, Hawley near Devonport, 5. ii. 1952—Cribb.
Extra-Tasmanian distr.: Queensland, India, S. Africa, Atlantic Ocean.

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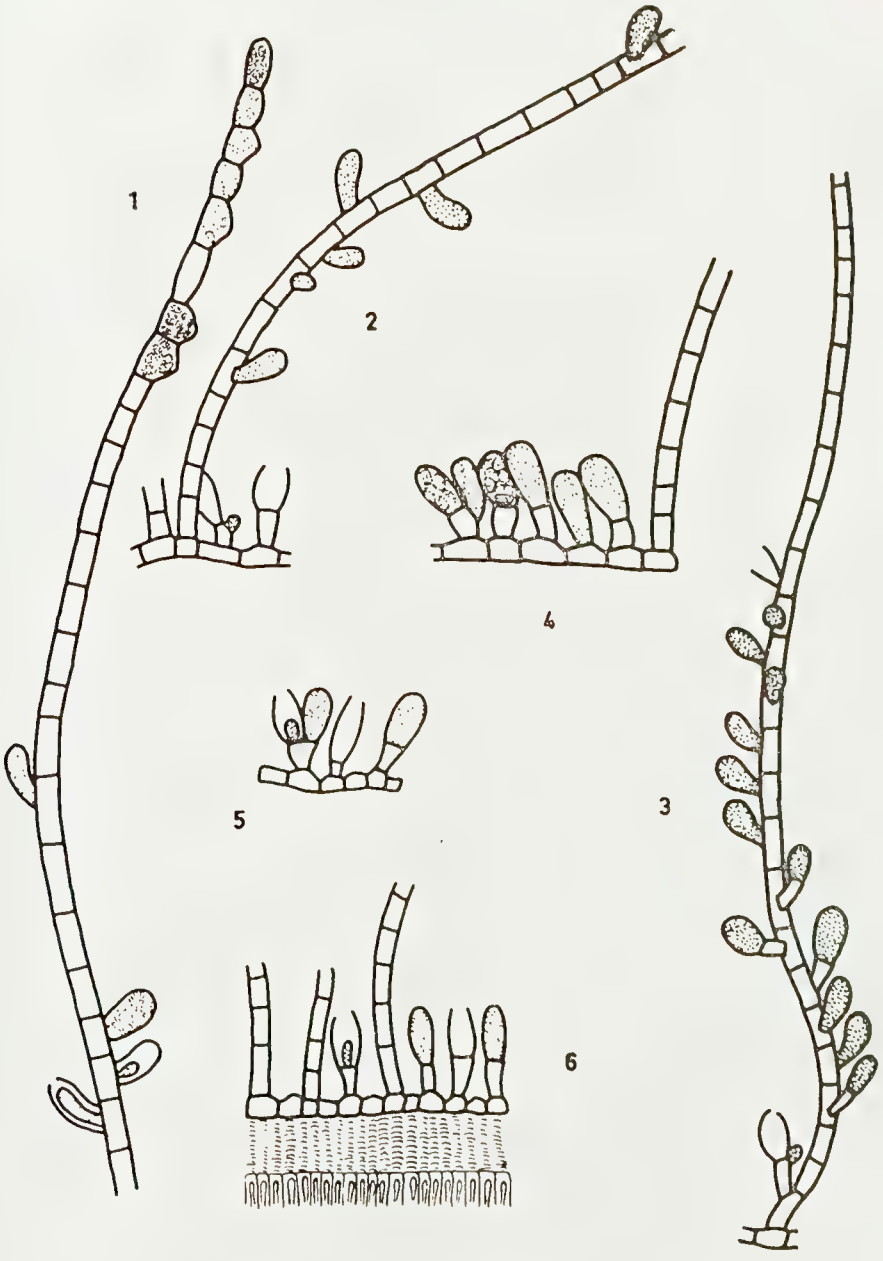

Plate 1

Fig. 1-6.—*Sporocladopsis novae-zelandiae* Chapman.—1, erect branch with lateral and intercalary sporangia; 2, basal filament with long erect sporangia-bearing branch and short 1-celled branches with terminal discharged sporangia; 3, erect long branch with lateral sessile and pedicellate sporangia; 4, basal filament with an erect long branch and with pedicellate and sessile sporangia; 5, basal filament with pedicellate sporangia; 6, thickened cuticle of *Sarcophycus potatorum* beneath basal filament of *Sporocladopsis*. All x 375.

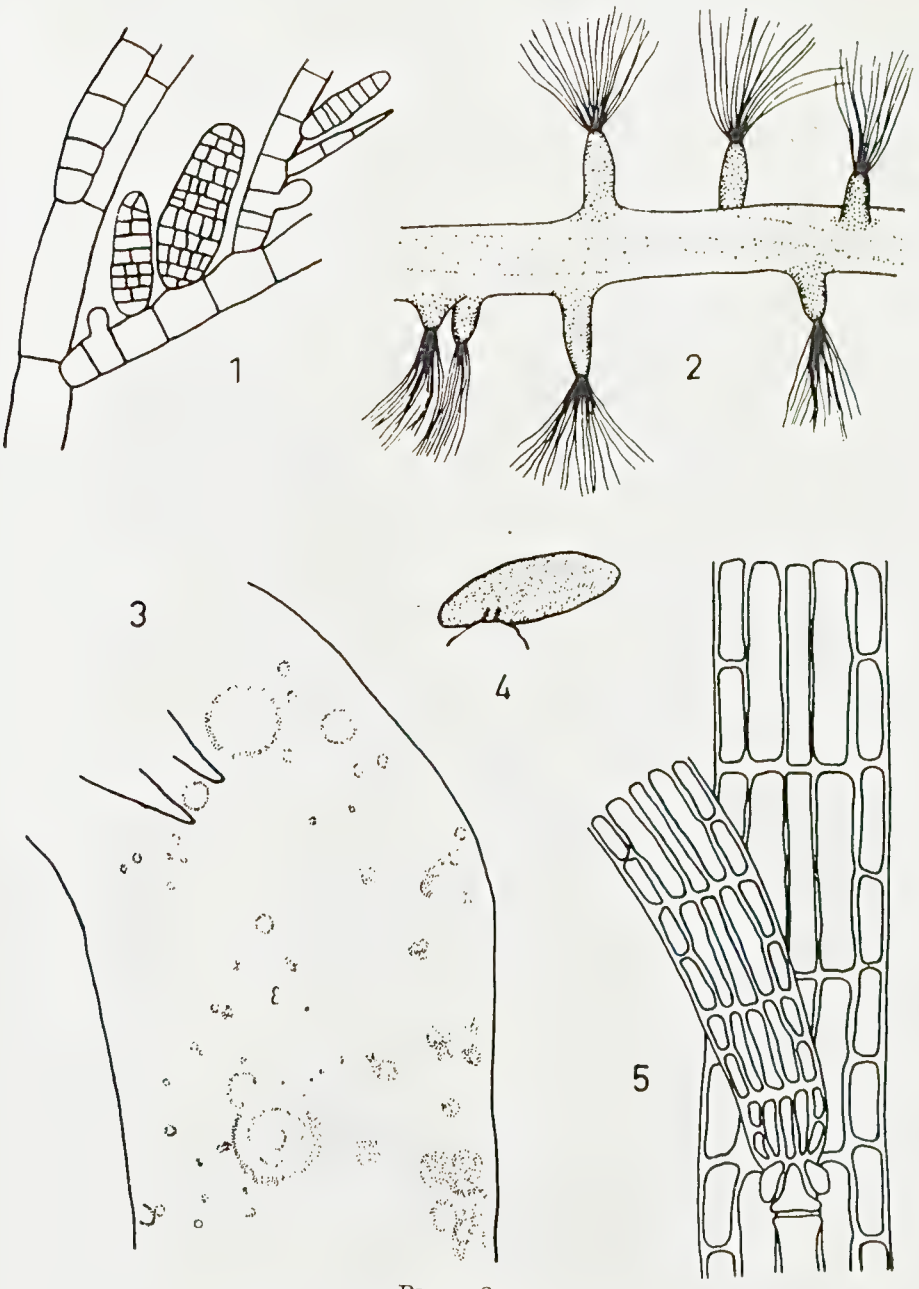

Plate 2

Fig. 1.—*Ectocarpus mitchellae* Harvey.—branch with plurilocular sporangia. x 250.

Fig. 2.—*Sporochnus apodus* Harvey.—portion of branch with receptacles. x 11.

Fig. 3.—*Sporocladopsis novae-zelandiae* Chapman.—colonies on thallus of *Sarcophycus potatorum*. x 1.

Fig. 4.—*Rhipiliopsis peltata* (J. Ag.) A. & E. S. Gepp.—whole plant. x 1·7.

Fig. 5.—*Platysiphonia miniata* (Ag.) Boergs.— portion of a branch. x 250.

Plate 3

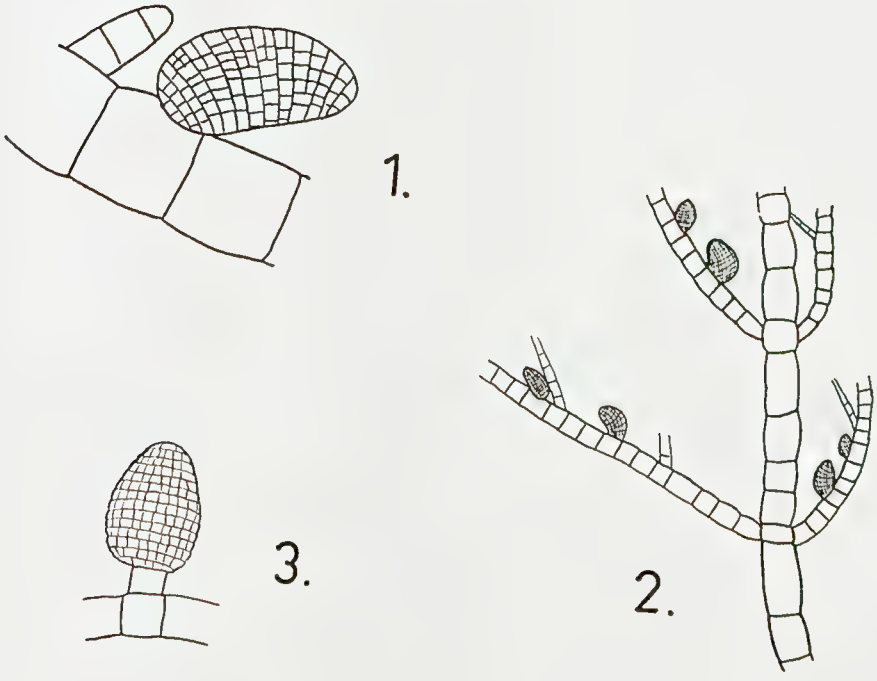

Fig. 1-2.—*Ectocarpus granulosus* (Smith) C. Ag.—5, plurilocular sporangium. x 235. 6, main axis with branches bearing plurilocular sporangia. x 43.
Fig. 3.—*Ectocarpus globifera* Kuetz.—plurilocular sporangium on main axis. x 106.

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"Ordinary people" in the first settlements. By W. T. DOWSETT. (*abstract*) 1946, p. 136.
Péron in Tasmania. By L. A. TRIEBEL. 1947, p. 63-68.
Pirates at Recherche Bay, or the loss of the brig. "Cyprus". By E. R. PRETYMAN. v. 88, p. 119-128.
The political economy of Van Diemen's Land. By K. M. DALLAS. (*abstract*) 1948, p. 160.
The port of Launceston. By W. HART (*abstract*) v. 87, p. xvii.
The rise and fall of Charles Swanston. By W. H. HUDSPETH. 1948, p. 1-16.
Some account of early Tasmanian sealing and whaling. By W. E. L. H. CROWTHER. (*abstract*) 1948, p. 166.
Some aspects of early printing and the advancement of learning. By D. H. BORCHARDT. (*abstract*) v. 88, p. xv.
Some new aspects of Tasman's visit to the east coast of Tasmania in 1642. By A. L. MESTON. v. 87, p. 167-174.
Some notes on Paterson's Plains, its pioneers and early life. By KARL R. VON STIEGLITZ. (*abstract*) 1948, p. 164-165.
The story of Mary Mack and her daughter Elizabeth Mary Mack. By W. H. HUDSPETH. 1949, p. 77-81.

Medicine and Public Health

Chemo-therapy of cancer. By J. B. POLYA. (*abstract*) v. 86, p. 143-145.
Nutrition problems in Tasmania. By F. W. CLEMENTS. 1945, p. 1-12.

Meteorology and Astronomy

The importance of reports from sub-antarctic stations and from shipping in forecasting in the Tasmanian region. By V. J. BAHR. (*abstract*) v. 87, p. xviii.
The scintillation of radio stars. By G. H. NEWSTEAD. (*abstract*) v. 89, p. ix-x.
Some recent astronomical developments. By C. BISDEE. (*abstract*) v. 88, p. xiv.

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Architecture in pre-war Europe. By OTTO R. HELLWIG. (*abstract*) 1947, p. 173.
Colour photography. By H. J. KING. (*abstract*) v. 87, p. xviii.
Democracy, Swiss pattern. By W. N. OATES. (*abstract*) v. 87, p. xii.
Highway rambles in Tasmania, with some excursions into architecture. By ROY SMITH. (*abstract*) v. 87, p. xviii.
Hydro-electric developments in Tasmania. By A. W. KNIGHT. (*abstract*) 1948, p. 165.
INDEX—Author index to papers published in the "Papers and Proceedings of the Royal Society of Tasmania", 1898-1944. 1945, p. 141-156.
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Linguistic changes in name in Tasmania with special reference to those of Scottish origin. By W. SUTHERLAND. (*abstract*) 1950, p. 160.
The modern museum. By JOSEPH PEARSON. (*abstract*) 1949, p. 278-279.
Recent hydro-electric developments in Tasmania. By W. E. McLEAN. (*abstract*) 1945, p. 164.
Scenery preservation in Tasmania. By J. B. THWAITES. (*abstract*) v. 86, p. 155.
Science and civilisation. By C. LOFTUS HILLS. (*abstract*) 1949, p. 285.
Some account of early Tasmanian sealing and whaling. By W. E. L. H. CROWTHER. (*abstract*) 1948, p. 166.

Physics, Geophysics, Chemistry, &c.

The attack on modern chemistry by the Soviet Union. By J. B. POLYA. (*abstract*) v. 87, p. xi.
An introduction to geophysics. By J. B. BONIWELL. (*abstract*) v. 86, p. 155.
On the growths of continents. By J. T. WILSON. 1950, p. 85-111 (*R. M. Johnston Memorial Lecture.*)
Radar. By L. H. MARTIN. (*abstract*) 1946, p. 137-142. (*R. M. Johnston Memorial Lecture*)

Sociology

Racial migrations and relations. By T. GRIFFITH TAYLOR. (*abstract*) 1948, p. 158-159. (*R. M. Johnston Memorial Lecture*).
Some aspects of apartheid in Southern Africa. By P. SCOTT. (*abstract*) v. 88, p. xvi.

Travel and Exploration

The Australian Antarctic Expedition, 1948: Macquarie Island. By NORMAN R. LAIRD. (*abstract*) 1949, p. 285.
Experiences in the Antarctic. By P. G. LAW. (*abstract*) v. 89, p. xii.
In the footsteps of Sir John Franklin overland from Lake St. Clair to the Gordon River. By J. B. THWAITES. (*abstract*) v. 89, p. vii-ix.
Jorgensen's journey across the Central Plateau—September-October, 1826. From papers of the late A. L. Meston. *Ed.* by W. MESTON and R. A. V. McCULLOCH. v. 89, p. 107-123.
Life on Macquarie Island By C. L. SPEEDY. (*abstract*) 1950, p. 160.
A trip to Ayers Rock, Central Australia. By W. BRYDEN. (*abstract*) v. 88, p. xvii.

Zoology—Invertebrate

Annulata.

Pontobdella tasmanica nom. nov. (Hirudinea.) By V. V. HICKMAN. 1946, p. 27.

Arthropoda.

(*a*) *Crustacea.*

The life of the crayfish. By V. V. HICKMAN. (*abstract*) 1947, p. 170.
New species of *Astacilla* from Tasmanian waters. By ERIC R. GUILER. 1948, p. 45-64.
Notes on the Tasmanian marine crayfish, *Jasus lalandii* (Milne Edwards). By V. V. HICKMAN. 1945, p. 27-38.
A preliminary description of *Fabia hickmani*, sp. nov. (Pinnotheridae.) By ERIC R. GUILER. 1949, p. 67-72.
Some facts about scallops from diving investigations. By A. M. OLSEN. (*abstract*) v. 88, p. xiii-xiv.
A summary of the Tasmanian Phreatoicids: a contribution to the Biological Survey of Tasmania. By G. E. NICHOLLS. 1945, p. 55-61.

(*b*) *Insecta.*

Bees—the production of pedigree stock. By T. D. RAPHAEL. (*abstract*) 1948, p. 161.
New data on Tasmanian water-mites (Hydrachnellae) with a list of recorded species. By L. SZALAY. v. 87, p. 73-80.
A note on ghost moths—family Hepialidae. *Abantiades hyalinatus* (Herrick Schaffer). By J. R. CUNNINGHAM. v. 89, p. 151.
Note on *Hesperilla chrysotricha plebeia* Waterhouse (Lepidoptera-Hesperiidae). By L. E. COUCHMAN. 1946, p. 29-30.
Notes on some Tasmanian and Australian Lepidoptera-Rhopalocera with descriptions of new forms and subspecies. By L. E. COUCHMAN, v. 88, p. 67-79.
Notes on the geographical races of *Hesperilla chrysotricha* Meyrick and Lower (Lepidoptera-Hesperiidae). By L. E. COUCHMAN. 1948, p. 65-73.

Notes on the Lepidoptera-Rhopalocera of Tasmania. By L. E. COUCHMAN. 1945, p. 49-53.
The nutritional requirements of insects. By L. W. MILLER. (*abstract*) 1946, p. 132.
A provisional check-list of the Acridoidea of Tasmania (Orthoptera). By K. H. L. KEY. v. 86, p. 127-130.
A study of the Tasmanian Psocoptera with descriptions of new species. By B. A. B. EDWARDS. 1949, p. 93-134.
A survey of the Aphids in Tasmania. By L. W. MILLER. (*abstract*) 1949, p. 279-280.

(*c*) *Arachnida.*

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The identity of spiders belonging to the genus *Amaurobioides* Cambridge. By V. V. HICKMAN. 1950, p. 1-2.
The morphology and habits of spiders. By V. V. HICKMAN. (*abstract*) 1949, p. 283.
A new genus of Pseudogarypin Pseudoscorpions possessing pleural plates. By J. C. H. MORRIS. 1947, p. 43-47.
New Phoroncidiinae and the affinities of the New Zealand spider *Atkinsonia nana* Cambridge. By V. V. HICKMAN. 1950, p. 3-24.
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The taxonomic position of *Idiogarypus hansenii* (With). By J. C. H. MORRIS. 1947, p. 37-41.

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A revision of the Tasmanian Hydroida. By MICHAEL M. HODGSON. 1949, p. 1-65.

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Contributions to the freshwater microfauna of Tasmania. Pt. 1—Copepoda. By VINCENZ BREHM. v. 87, p. 33-62.
Contributions to the freshwater microfauna of Tasmania. Pt. 2—Daphnidae, Bosminidae, Cytheridae, &c. By VINCENZ BREHM. v. 87, p. 63-72.

Mollusca.

A systematic list of the mollusca of Tasmania, Australia. By RONALD C. KERSHAW. v. 89, p. 289-355.

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Notes on the occurrence of the nematode *Mermis nigrescens* Dujardin and its effect on the common earwig in Tasmania. PETER W. CROWCROFT. 1947, p. 59-62.

Platyhelminthes.

Arrangement of the female organs and ducts in the Cestode genera *Oochoristica* Lühe and *Linstowia* Zschokke. By J. L. HICKMAN. v. 89, p. 99-105.
A description of *Sterrhurus macrorchis* n. sp., with notes on the taxonomy of the genus *Sterrhurus Looss* (Trematoda-Hemiuridae). By PETER W. CROWCROFT. 1945, p. 39-48.
A new digenetic trematode from the Barracouta (Syncoeliidae-Digenea). By PETER W. CROWCROFT. 1947, p. 49-57.
A new Turbellarian parasitic in the sea-star, *Coscinasterias calamaria* (Gray). By V. V. HICKMAN and A. M. OLSEN. v. 89, p. 55-63.
Note on *Anthobothrium hickmani*, a new cestode from the Tasmanian electric ray (*Narcine tasmaniensis* Richardson). By PETER W. CROWCROFT. 1946, p. 1-4.
A revised description of *Dolichopera macalpini* Nicoll, 1914. (Plagiorchiidae-Trematoda.) By PETER W. CROWCROFT. 1949, p. 73-76.

Some digenetic trematodes from fishes of shallow Tasmanian waters. By PETER W. CROWCROFT. 1946, p. 5-25.
Two new cestodes (Genus *Oochoristica*) one from the lizard *Egernia whitii*, the other from the bat, *Nyctophilus geoffroyi*. By J. L. HICKMAN. v. 88, p. 81-104.
Two new rhabdocoel Turbellarians parasitic in Tasmanian Holothurians. By V. V. HICKMAN. v. 89, p. 81-97.

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The affinities of the rat-kangaroos (Marsupialia) as revealed by a comparative study of the female urogenital system. By JOSEPH PEARSON. 1945, p. 13-25.
The American opossum, the most primitive marsupial. By H. C. REYNOLDS. (*abstract*) v. 89, p. x.
The evolution of the mammalian placenta. By JOSEPH PEARSON. (*abstract*) 1946, p. 134-136.
The female urogenital system of *Antechinus* (Marsupialia). By JOSEPH PEARSON and JOHN M. De BAVAY. 1950, p. 137-142.
A further note on the female urogenital system of *Hypsiprymnodon moschatus* (Marsupialia). By JOSEPH PEARSON. 1949, p. 203-209.
Neonatal length as a linear function of adult length in Cetacea. By E. O. G. SCOTT. 1948, p. 75-93.
Notes on the female urogenital system of *Tarsipes spenserae* (Marsupialia). By JOHN M. De BAVAY. 1950, p. 143-149.
Observations on the surface structure of the hairs of Tasmanian monotremes and marsupials. By A. G. LYNE and T. S. McMAHON. 1950, p. 71-84.
Recent researches in marsupial comparative anatomy and embryology. By JOSEPH PEARSON. (*abstract*) v. 86, p. 149-152.
The relationships of the Potoroidae to the Macropodidae (Marsupialia). By JOSEPH PEARSON. 1949, p. 211-229.
Size variations in Tasmanian rabbits. By M. B. LIEDERMAN. v. 89, p. 125-130.
Syndactyly in the manus of a marsupial. By A. G. LYNE. v. 87, p. 31-32.
The urogenital system of the Dasyurinae and the Thylacininae (Marsupialia, Dasyuridae). By JOSEPH PEARSON and JOHN M. De BAVAY. v. 87, p. 175-192.

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Age and growth of trout from their scales. By A. G. NICHOLLS. (*abstract*) v. 86, p. 148.
Fish welfare. By HAROLD THOMPSON. 1947, p. 1-19. (*Clive Lord Memorial Lecture.*)
Freshwater fisheries problems. By E. PERCIVAL. (*abstract*) 1949, p. 284.
Freshwater fishing problems. By A. DUNBAVIN BUTCHER. (*abstract*) 1949, p. 285.
A new Bothid fish from eastern Tasmania. By DUDLEY E. KURTH. v. 88, p. 45-47.
Observations on some Tasmanian fishes: Pt. VI.* By E. O. G. SCOTT. v. 87, p. 141-166.
Observations on some Tasmanian fishes: Pt. VII. By E. O. G. SCOTT. v. 89, p. 131-146.
Sea fisheries research, with special reference to Australia. By MAURICE BLACKBURN. (*abstract*) 1948, p. 165-166.

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PAPERS AND PROCEEDINGS

OF

The Royal Society of Tasmania

Volume 91

Edited by William Bryden

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1957.

The Royal Society of Tasmania

Volume 91

LIST OF OFFICE BEARERS 1957

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Her Majesty the Queen.

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His Excellency the Governor of Tasmania (Rt. Hon. Sir Ronald Cross, Bt., K.C.M.G., K.C.V.O.).

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Mr. A. M. Hewer.

Standing Committee:

Mr. J. W. C. Wyett, Dr. W. V. Teniswood, Mr. G. E. Hale and Dr. W. Bryden.

The Royal Society of Tasmania

Papers and Proceedings Volume 91

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Royal Society of Tasmania.

Annual Report, 1956.

The year marked a further period of progress and it was gratifying to note the increase in membership and the formed opinion, of a number of members, that many people, who are not members, would like to be associated with the Society. It is largely by the help of present members that the Society increases its numbers so the co-operation of all is sought to bring people interested in science, history and art, into membership.

The Annual Meeting was held in the Society's rooms, Tasmanian Museum, on 6th March, 1956.

The President, His Excellency the Governor (Sir Ronald Cross), presided.

The following Office-bearers were elected:—

Vice-President: Under the Society's Rules, Professor T. Hytten retired from the office of Vice-President and Dr. W. L. Crowther was appointed to the vacancy (retiring 1958).

Hon. Secretary and Librarian: Dr. W. Bryden.

Hon. Treasurer: Mr. G. E. Hale.

Hon. Auditor: Mr. A. M. Hewer.

Council: Under Rule 21, Mr. J. W. C. Wyett and Dr. W. L. Crowther retired as members of the Council, and Professor T. Hytten and Mr. C. Bisdee were elected in their place, for a period of three years.

The Council made the following appointments for the year:—

(*a*) Standing Committee: Dr. D. Martin, Mr. L. W. Miller, Dr. W. V. Teniswood and the Hon. Secretary, Dr. W. Bryden.

(*b*) Tasmanian Museum Trustees: Professor A. Burn and Dr. C. Loftus-Hills.

(*c*) Botanical Gardens Trustees: Mr. S. Angel.

(*d*) Representative to the Library Association: Dr. W. Bryden.

(*e*) Nomenclature Board: Mr. E. R. Pretyman.

Meetings: Ten ordinary meetings and one special meeting were held during the year when the following lectures were given:—

March: "Glimpses of Brazil and the Brazilians", by Professor K. Caster, University of Cincinnati, U.S.A. (with songs by Mrs. Caster).

April: "Historic Buildings", by Mr. Roy Smith (with illustrations).

May: "A Biologist in Chile", by Dr. E. R. Guiler.

June: "Forty Years of Engineering", by Professor Alan Burn.

July: "Entomology in North America", by Mr. L. W. Miller.

Aug.: "Life with the Australian National Antarctic Research Expedition", by Mr. N. R. Parsons.

Sep.: "The Pearl of Africa", by Dr. Emyr Williams.

Oct.: "Biology of the Scallop", by Mr. A. M. Olsen.

Nov.: "Some Aspects of American Education", by Mr. M. R. Banks, B.Sc., Senior Lecturer in Geology, University of Tasmania.

Library: During the year 429 volumes (books and journals) were added to the Library in addition to a number of reports and pamphlets from British and foreign institutions and learned societies. The number of institutions on the exchange list is now 300. The Library now consists of 30,939 volumes.

Membership: The Society consists of the following members:—

Honorary Members		2
Corresponding Members		1
Ordinary Members—		
Class A = 280		
Class B = 175		
		455
Life Members		32
Associate Members		20
TOTAL		510

During the year (52) fifty-two new members were added to the roll while (24) twenty-four names were removed from the lists owing to resignations, deaths, &c.

Deaths: The Council of the Society regrets having to record the deaths of the following members:—Mr. A. P. Findlay, Miss J. A. Fletcher, Mr. A. M. Graves, Mr. E. G. Record, and Mr. C. H. D. Chepmell.

Subscriptions: The Council of the Society spent considerable time, during the early months of the year, considering the question of finances of the Society. It was agreed that if the Society was to continue and if the Papers and Proceedings and Library were to remain as at present subscriptions would have to be increased. In October a special meeting was called and Rule 33 was amended to increase subscriptions by 10s. per annum. Rule 40 (Associate Members) was also altered accordingly.

Papers and Proceedings: The Society is grateful to the Government of Tasmania for providing amounts of money to meet the increased cost of Volume 89 and also for agreeing to continue the donations which enable the Society to continue to print this scientific journal.

The Society would once again thank the University of Tasmania for its part in financing the Papers and Proceedings.

Thanks: The Society records its thanks to the many who have assisted by donations of money, books, &c., and to all who have helped in many ways during the year.

ROYAL SOCIETY OF TASMANIA.

Statement of Receipts and Payments to 31st December, 1956.

Receipts.

	£	s.	d.
Balance from last Account	5	16	11
Subscriptions:			
£2 260 + £8 15s. =	528	15	0
£2 10s. (1957) 2 less 10s. =	4	10	0
£1 10s. 162 + 10s. =	243	10	0
£2 (1957) 3 =	6	0	0
15s. 19 =	14	5	0
	£797	0	0
Sale of publications	61	10	11
Rental of Royal Society Room	77	7	6
Donation	2	0	0
Refund, Hydro-Electric Commission, Tasmanian Museum	104	0	0
University of Tasmania Grant—Librarian	475	0	0
Friends of Museum—contribution conversazione	40	0	0
Refunds	2	5	0
Transferred from Reserve, cost postage, plus Papers and Proceedings, Volume 90	25	18	3
	£1,590	18	7

Payments.

	£	s.	d.
Salaries	746	5	8
Petty cash	104	0	0
Library	158	18	11
Stationery	55	9	6
Equipment	31	18	0
Northern Branch—share subscriptions, 1955	110	17	6
Miscellaneous	44	8	6
Light and power	184	5	10
Postage of Papers and Proceedings, Volume 90	25	18	3
Expenses conversazione	49	17	7
Insurance	25	10	0
Telephone	10	10	0
	1,547	19	9
Balance to next Account	42	18	10
	£1,590	18	7

G. HALE, *Hon. Treasurer.*

F. C. WOLFHAGEN, *Vice-President.*
W. BRYDEN, *Hon. Secretary.*

Northern Branch.

Annual Report, 1956.

At the Annual General Meeting of the Royal Society of Tasmania (Northern Branch) held at the Queen Victoria Museum on March 23rd, 1956, the following were elected to the Council under the Rules of the Branch:

Chairman: Mr. G. H. Crawford (1956, 1957).

Vice-Chairman: Mr. W. Hart (1956, 1957).

Hon. Secretary/Treasurer: Mr. W. F. Ellis (1956).

Council Members: Mr. R. S. Smith (1956, 1957); Mr. K. R. von Steiglitz (1956, 1957); Mr. G. H. Willing (1956, 1957).

The Council Members retaining their seats for the year were: Mr. G. H. Stancombe (1956); Dr. C. Craig (1956).

The retiring Chairman and Council Members were thanked for the services they had rendered to the Society during their terms of office.

Meetings: Nine general meetings and one special meeting were held during the year at which the following papers were read:—

February 24, 1956: "The Coaching Era in Tasmania", by Mr. G. H. Stancombe.

March 23, 1956: "Some Aspects of Heraldry", by Mr. J. P. D. Bingham.

April 9, 1956: "Australian Furred Animals—Past and Future", by Mr. E. Le G. Troughton.

April 27, 1956: "Some Glimpses of Brazil and Brazilians", by Professor and Mrs. K. E. Caster.

June 8, 1956: "Early Days in Papua (British New Guinea)", by Mr. L. S. Bethell.

July 27, 1956: "Some Aborigines—Ancient and Modern", by Mr. W. F. Ellis.

August 17, 1956: "Cybernetics, the Theoretical Background to Automation and some of its Implications for Biology", by Mr. E. O. G. Scott.

August 27, 1956 (Special Meeting): "Nineteenth Century English Painting", by Dr. T. S. R. Boase.

September 24, 1956: "The Fabulous Era of Australian Mining", by Mr. Geoffrey Blainey.

December 10th 1956: "Our Legal Heritage—a comparative study of British and Soviet Law", by Mr. G. H. Crawford.

Excursions.

April 29, 1956: "Lake House" and "Burlington", Cressy, led by Mr. R. S. Smith.

September 1, 1956: Australian Aluminium Production Commission Plant, Bell Bay.

October 27, 1956: Department of Agriculture Research Farm, Cressy and Laboratories, Mt. Pleasant.

Membership: Fourteen members were elected to the Northern Branch during 1956, the total membership now being—

Life Members	14
Ordinary Members	143
Associate Members	11

Library: Three books were added to the Branch Library during the year under review.

Publications: "The Penal Settlements of Van Diemen's Land" is still being distributed through commercial retailers, the Queen Victoria Museum and the Society.

The preparation of a biography and anthology of the work of John Helder Wedge has been commenced and most of the necessary material gathered. It is hoped to issue this publication during 1957.

ROYAL SOCIETY OF TASMANIA.

(Northern Branch.)

Statement of Accounts at December 31st, 1956.

Receipts.	£	s.	d.
Balance at 1.1.1956	111	16	6
Subscriptions	110	17	6
Bank interest	4	10	0
Sales of publication	14	6	1
	£241	10	1

Expenditure.	£	s.	d.
Lectures	39	12	11
Library	10	7	2
Printing and advertising	12	16	8
Postages and petty cash	41	3	1
Sundries	8	2	10
Balance carried forward	129	7	5
	£241	10	1

J. R. FORWARD, *Auditor.*

F. ELLIS, *Hon. Secretary/Treasurer.*

A RECONNAISSANCE OF THE CORINNA-PIEMAN HEADS AREA—GEOLOGY

By

Alan Spry and Ramsay Ford

Department of Geology, University of Tasmania

(With 1 Text Figure and 1 Plate)

ABSTRACT

Slates, phyllites, quartzites, conglomerates and dolomite of Pre-Cambrian age occur in a faulted anticline. They have been intruded by pre-metamorphic basic rocks which occur as a dyke swarm, by Cambrian ultrabasic rocks around Heazlewood and by Devonian granites at the Pieman Heads. The granite lies along the axis of the anticline.

The Pre-Cambrian rocks have been divided into four sets of beds which have been named. They have suffered low-grade regional metamorphism with superimposed thermal metamorphism near the granite. A major fault which occurs along the Donaldson River is a member of a system of faults with north-easterly trend. Silicified conglomerates and basalt of Tertiary age overlie the older rocks unconformably along the Corinna Road.

INTRODUCTION

A reconnaissance was made over parts of an area to the west and north of Corinna. Traverses were made along the Pieman River from the Heads up to the rapids near the Paradise River; from the Heads south to Conical Rocks; from the Heads north to just below the Interview River; from the Heads north-east to the plains between the Interview River and Mt. Donaldson; from Corinna south for a few miles along the track to Zeehan; along the main road north to Bald Hill; along the track towards the Savage River from the main road; and along the track into the Whyte and Rocky Rivers.

An attempt was made to unravel the complex structure and stratigraphy of the Pre-Cambrian rocks but little could be achieved in such a short time. Full use was made of air photos and much of the major structure was obtained by photo-interpretation. The dyke swarm was also mapped by this method.

The field work was shared by the two authors, while the petrology, structure and the preparation of this account was done by Spry.

PREVIOUS LITERATURE

Very little was known of most parts of this rather inaccessible area. Ward (1911) described the sediments briefly and mentioned the occurrence of slates, quartzites and conglomerates which he tentatively regarded as of Cambro-Ordovician age, while the dolomite south of Rupert Point was considered to be possibly Gordon Limestone. The Tertiary conglomerates were also found in a number of places. Ward mapped portions of the dyke swarm and described some members although he did not appreciate its extent; he considered the dykes to be coeval with the Cambrian basic and ultrabasic intrusions common to the West Coast of Tasmania. The granite was mapped and correlated with the Heemskirk mass to the south.

Smith (1897) and Twelvetrees (1900, 1903) outlined the geology along the Corinna Road between Bald Hill and Corinna. Twelvetrees (1900) described the amphibolites near the Rocky and Whyte Rivers and also discussed the occurrence of alluvial gold at Long Plains in his 1903 report, while Blake (1939) briefly discussed the Corinna alluvial goldfield.

PRECAMBRIAN ROCKS

Sediments

There is an unknown thickness (at least 10,000 ft.) of unfossiliferous sediments in the area. They are chiefly quartzites and phyllites with minor slates, conglomerates, and dolomite. The rocks may be divided regionally into four distinct groups but their mutual relations are not yet known.

Coastal Area

The rocks which exend northwards from the Pieman Heads to Rupert Point and beyond and which are confined by the granite to the east, consist of phyllites, quartzites, conglomerates and dolomite with a general strike of 330° and steep dips to the west. Severe contortion and overturning towards the east occurs in several places, though drag folds and cleavage indicate that the sequence as a whole is not overturned.

These rocks will be referred to as the Rupert Beds.

The quartzites are both well-bedded and massive and are usually white. Some specimens* (5788) show a disinct lineation parallel to the dip. A quartzite (5792) from just south of Rupert Point shows a very marked, patchy colouration in cream and dark-grey, which is due to irregular pigmentation by secondary finely granular haematite. Under the microscope the quartzites show evidence of crushing giving a "mortar" texture with large ragged quartz grains set in a fine quartz-sericite matrix.

The phyllites (5776, 5777) are grey to cream in colour with a marked fissility which is usually at a high angle to the bedding. Thin sections show that they consist of a fine-grained aggregate of quartz, muscovite and biotite accompanied by tourmaline, magnetite, rutile and feldspar in some specimens.

* Specimens in the collection of the Geology Department, University of Tasmania.

For "Pre-Cambrian" read "Precambrian" throughout the paper.

A number of conglomerate beds occur along this stretch of coast as shown in plate I, No. 3. They appear to be quite thin and lenticular with probably a maximum thickness of 20 feet and thus the thickness of 300 feet reported by Ward (1911) is not confirmed. The boulders are well-rounded and are composed chiefly of quartzite in an argillaceous matrix. The conglomerates have been sheared in some places producing a distinct schistosity in the matrix (as in 5789), and elongating some pebbles (5790). Plate I, No. 4 shows that the elongation of the pebbles is parallel to the cleavage in both the conglomerate and the associated beds, but is at an angle to the bedding. It is interesting to note that Ward (1911) reported that in certain beds only the slate fragments were deformed while the quartzite pebbles were not. The authors also noticed that in some cases only a few of the quartzite pebbles were deformed but further comment on these phenomena is deferred until a more complete study now in progress of the deformed conglomerates of Tasmania is to hand. The phyllite (5793) associated with the most southerly exposure of the conglomerate showed a weak lineation parallel to the direction of elongation of the pebbles with a stronger one at right angles.

A thin, impure, dark-grey dolomite (5789) occurs about a mile and a half south of Rupert Point. It is conformable with the other sediments and thus is not Silurian as suggested by Ward (1911).

Interview River Plains Area

This belt of country, which extends from a point east of Mt. Sunday southwards to the coast below Conical Rocks and which includes the button-grass plains of the upper reaches of the Interview River, is underlain by rocks which differ from those of the coastal belt. These rocks are phyllites and quartzites which have been intruded by the Pre-Cambrian dyke swarm. In general the rocks strike at 30° and dip moderately to the south-east although there is a considerable change in the strike to east-west on the north side of the Pieman River. The sediments strike parallel to the coast on the southern side of the Pieman Heads where they dip chiefly to the south-east with a good deal of contortion. These rocks are separated from the sediments to the west by the granite and differ from them in lacking conglomerates and dolomite and by being predominantly phyllitic with abundant basic intrusions. The phyllites are typified by containing intraformational structures such as slumping and mud flakes (5771, 5765), as well as having a more pronounced cleavage. They are separated from the beds at Mt. Donaldson by the Donaldson River Fault and differ from them in showing a little higher grade of regional metamorphism and in having abundant intrusions. These sediments will be referred to as the Interview Beds, although they are probably equivalent to Ward's (1911) Balfour Slates and Sandstones.

Mt. Donaldson Area

The Donaldson Beds consist of quartzite, conglomerate and black slate. This group lacks the intrusions which are typical of the Interview Beds and is less altered than the Rupert Beds. It is similar to the latter in that it contains much quartzite, conglomerate and black slate (5809).

The Area North of Corinna.

Between Corinna and Bald Hill, which is about 25 miles north along the Waratah Road, there are quartzites (many of them grey and impure, e.g., 5784), phyllites (5785) and some black graphitic slates (5786). The strike varies from about 340° to 10° and dips are usually to the east at 50° or more. The Precambrian rocks are bounded by the Bald Hill pyroxenite to the north-east and by the granite of the Meredith Range to the east, and will be referred to as the Corinna Beds.

There are glossy phyllites on the track to the Whyte River and these strike at 320°, dipping east at 70°. They have a pronounced cleavage and lineation. There are green schists and coarse, altered basic rocks along the river end of the track and the river itself. These are described later.

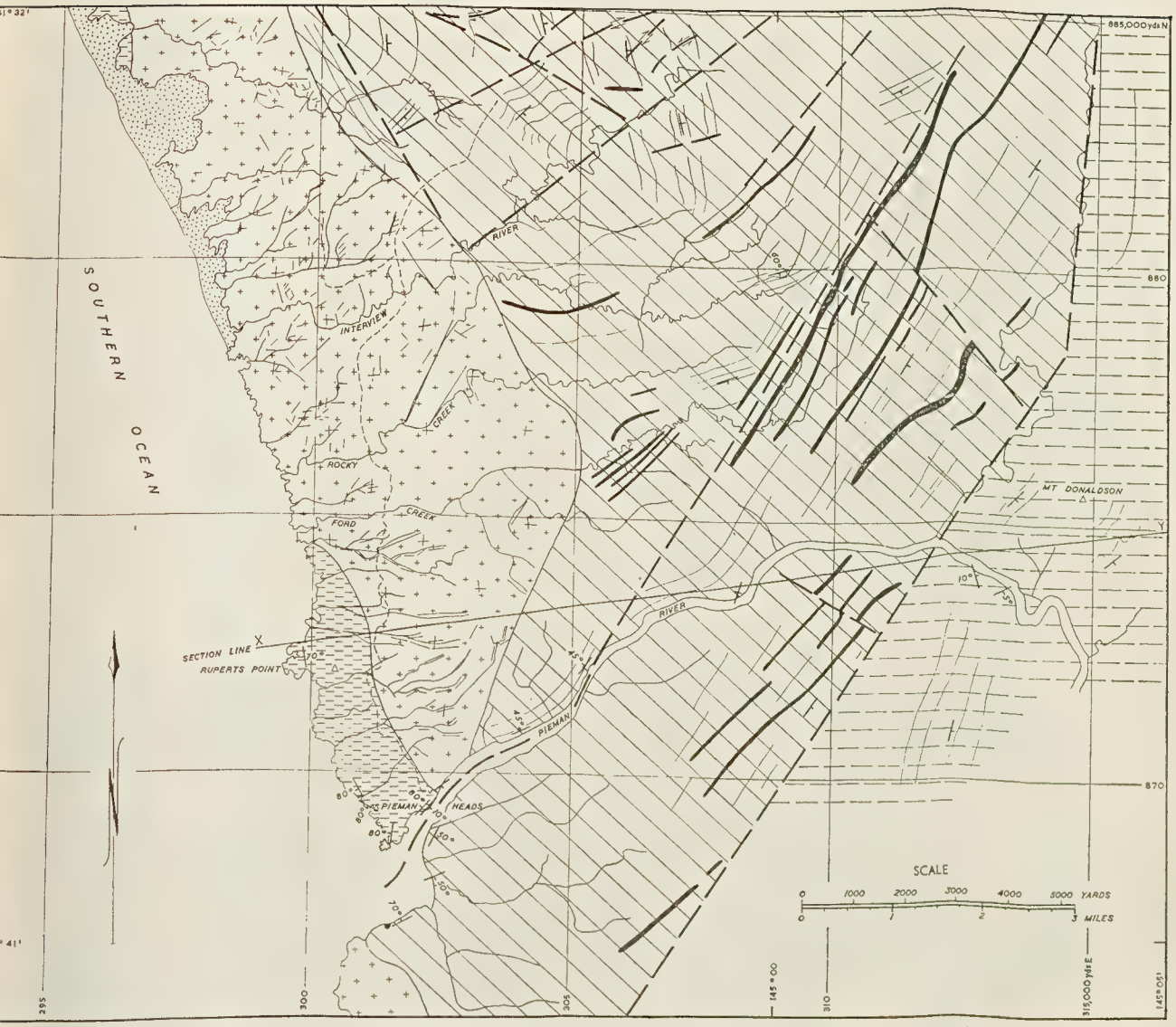
At the miners' hut on the Whyte River is a fine-grained, green lustrous schist (5794) which is cut by quartz veins and which has been mineralized. It consists of quartz and sericite with a little chlorite, iron ore, apatite and tourmaline. The quartz has been drawn out into strongly elongated aggregates parallel to the cleavage. Crenulation of the cleavage gives the rock a false cleavage and causes the macroscopic lineation.

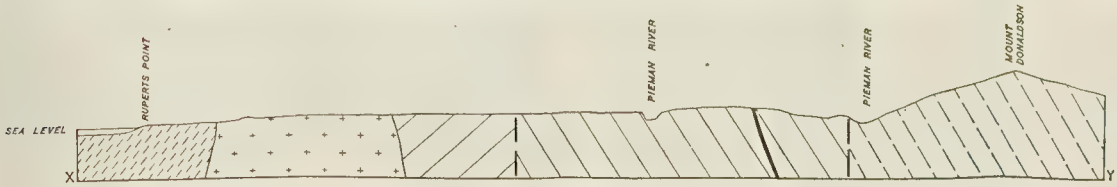
Basic Rocks

One of the most important features of the area is the swarm of basic to ultrabasic intrusions which extend from south of Conical Rocks across the Pieman, up to the east of Mt. Sunday and beyond Mts. Vera, Hadmar and Rosslyn. The intrusions are narrow, elongated bodies some of which are concordant while others are discordant. In some places they are parallel to the bedding and are sills but in most instances they are at a shallow angle or even perpendicular to the bedding. The longest is five miles in length and they are commonly over a mile long but only up to 200 feet in thickness. They are broken by the north-west and east-west sets of minor faults. Up to the present, over 40 intrusions have been found but inspection of air photos suggests that the swarm continues to the N.N.E. where a very large number of bodies extends for many miles. Investigations are now being carried out to determine the relationships between the dyke swarm and the dolerites at Rocky Cape (Spry, this volume). It is not impossible that the sediments in the Pieman Heads area are equivalent to the Rocky Cape Group and that the Cooee Dolerite is the less altered equivalent of the dyke swarm.

The amphibolites near the junction of the Whyte and Rocky Rivers are similar although more strongly metamorphosed and are regarded as being part of the same group. Varieties have been found showing all degrees of metamorphism giving types varying from slightly sheared dolerites to coarse feldspathic amphibolites.

Two distinct petrographic types have been distinguished in the dyke swarm but it is inevitable that detailed collecting would reveal much more variation. These rocks are being examined in more detail as part of the study of the Pre-Cambrian basic rocks of Tasmania.





LEGEND

Recent
- SAND DUNES

Devonian
- GRANITE

Precambrian
- DYKES
- DONALDSON BEDS
- RUPERT BEDS
- INTERVIEW BEDS

- FAULT
- ROCK BOUNDARY
- STRUCTURAL TRENDS
- 10° STRIKE AND DIP OF SEDIMENTS
- STRIKE OF VERTICAL JOINTS
- TRACK

Coordinates on Transverse Mercator Projection. Zone 7 based on Mt. Donaldson E. 314828, N.875663. Grid Convergence at the centre of this map is 00° 41' 30" E.

FIG. 1.—Reconnaissance geological map of the Pieman Heads area.

The most common variety is an altered dolerite which was described by Ward (1911) as an amphibolite and an example of this is (5806) which is a slightly metamorphosed and sheared dolerite consisting of ragged brown hornblende and plagioclase laths which are riddled with epidote. Ilmenite, leucoxene and quartz are present. The presence of a little biotite is possibly due to the granite which is about a half mile away.

Specimen (5804) is a more strongly altered dolerite consisting of irregular lenticular patches of ragged, pale amphibole (near tremolite) with ilmenite and leucoxene. There are a few bent feldspar crystals but the majority have been altered to very finely granular zoisite. Also present is a little fresh albite and quartz.

The second variety of dyke rock is typified by (5801) which is fine-grained, greenish-black and glittering. It consists entirely of chlorite with a texture which is decussate and unlike a normal igneous or regional metamorphic texture. There is a little iron ore present.

TABLE I.

	A	B
SiO_2	24·96	62·64
Al_2O_3	22·61	13·87
Fe_2O_3	2·13	1·18
FeO	23·50	3·17
CaO	Nil	6·16
MgO	15·50	6·33
Na_2O	Nil	4·99
K_2O	Nil	0·93
H_2O-	0·10	Nil
H_2O+	11·38	1·12
TiO_2	0·10	0·10
P_2O_5	Nil	Nil
NnO	0·22	0·11
	100·50	100·60

A. Chlorite rock, 5801, Interview River. Anal., Wt. St. C. Manson.

B. Amphibolite, 5795, Whyte River. Anal., W. St. C. Manson.

Comparison with the work of Orcel (1927) shows that it is the variety *ripidolite*. The recalculation of the analysis following Hey (1956) shows that the composition lies in the ripidolite field of Hey's classification.

	Recalculation of Analysis to Anhydrous Base	Atomic Proportions of Metal Ions	No. of Metal Atoms on Basis of 140
SiO_2	28·17	0·4694	2·59
Al_2O_3	25·51	0·5005	2·76
Fe_2O_3	2·40	0·0301	0·17
FeO	26·52	0·3691	2·04
MgO	17·49	0·4340	2·40
	100·09	Oxygen=2·536	

The chlorite is uniaxial positive with $\beta = 1{\cdot}621 \pm {\cdot}003$, and has a very low birefringence with anomalous blue interference colours. Thus the optical properties coincide quite well with Hey's ripidolite.

As the thin section of this specimen showed only chlorite and slight traces of magnetite, a powdered sample of the rock, from which magnetite had been removed, was X-rayed using CuK radiation and a Unicam 3 cm. radius powder camera. Allowance was not made for film shrinkage in obtaining the following X-ray pattern of the mineral.

Line No.	Intensity	θ (Degrees)	D
1	VS	3·25	13·60
2	VS	6·28	7·04
3	S	9·57	4·63
4	VS	12·70	3·50
5	VW	15·99	2·80
6	S	17·47	2·57
7	W	18·36	2·45
8	VW	18·91	2·38
9	W	19·91	2·26
10	S	22·65	2·00
11	W	24·23	1·88
12	VW	25·16	1·81
13	VVW	27·69	1·66
14	S	29·72	1·55
15	VW	30·65	1·51
16	VW	33·08	1·41
17	S	33·71	1·39
18	VVW	35·38	1·33
19	VVW	36·47	1·30
20	VVW	39·15	1·22
21	VVW	40·99	1·17
22	VVW	43·02	1·13
23	VVW	47·93	1·04
24	VVW	50·01	1·01

The chlorite rock is apparently the result of low-grade regional metamorphism on one of the dyke-rocks. The low silica, alkalies, and lime with high iron and magnesia suggests that some differentiation, either igneous or metamorphic, has taken place.

The rocks outcropping along the Whyte River, and the lower reaches of the track leading into it, are basic igneous rocks showing a slightly higher degree of regional metamorphism. These were recorded by Twelvetrees (1903). A fine-grained greenschist (5796) occurs about half a mile up the track west of the river. It is a green schistose rock consisting chiefly of pale-blue green actinolite with zoisite, biotite, pyrite, magnetite, chlorite and a little untwinned albite. About a quarter of a mile north of the intersection of the track with the Whyte River is a coarse, irregularly textured rock (5795) which consists of plagioclase, amphibole, sphene and quartz. The plagioclase (albite) is broken and bent with abundant inclusions, the amphibole is a pale-green actinolite, and the quartz shows undulose extinction. The analysis in Table I shows that the amphibolite resembles a basic igneous rock with spilitic affinities (4·99% Na_2O) in composition.

Structure

A number of structurally distinct units have been recognized and these are separated from each other mainly by faults or by granite.

(*a*) The coastal strip from the Pieman Heads north beyond Rupert Point contains the Rupert

Beds which strike generally at 330° and dip steeply to the west. Local contortion occurs and examples are shown in plate I, Nos. 1, 2 and 5.

(*b*) The Interview River plains are underlain by quartzites and phyllites of the Interview Beds. These strike at 30° regionally but locally there is minor folding. The strike is 350° in the Lagoon River area, 80° midway between the Pieman and the Interview Rivers and about 70° south of the Pieman Heads. Dips are moderate to steep towards the south-east but along the Pieman River just east of the granite the phyllites dip to the north-west. This may be due to drag along the fault which lies along the river.

(*c*) The Mt. Donaldson area is underlain by slates, quartzites and conglomerates of the Donaldson Beds which strike regionally at 30° but which are strongly contorted. Dips are flat (5° to 10°) along the Pieman River to the south-west of Mt. Donaldson but become steeper to the east. Inspection of the air photos of the Tikkawappa Plateau to the south reveals what may be a syncline overturned towards the west.

(*d*) The Corinna Road between Corinna and Long Plains passes over phyllites and quartzites of the Corinna Beds the strike of which swings from 340° to 10° with dips moderate to steep towards the east.

Apart from differing degrees of metamorphism, the Rupert Beds are similar to the Donaldson Beds while the rocks, phyllites and basic rocks of the Interview Beds are similar to those of the Corinna Beds and it is possible that all form a conformable sequence. Correlation with other Pre-Cambrian rocks in Tasmania is not yet possible. The general structure appears to be a broad anticline plunging to the south with an axis approximately parallel to the coast, cut by several large faults and intruded by granite. The sediments west of the granite dip to the west, while those to the east dip towards the east. Thus it appears that the axis has been faulted and intruded by granite.

Strong deformation in the extreme east and west of the area has given some rocks one or even two lineations. Some rocks show a lineation, formed by small crenulations or pebble elongation, which lies within the plane of the schistosity and usually plunges rather strongly to the south. This may be a "*b*" lineation parallel to the axis of the major folds but the "*b*" direction as determined by drag folds is extremely variable in both attitude and direction. The phyllite (5792) shows a strong lineation within the plane of the cleavage, perpendicular to the first lineation and this probably indicates "*a*". The quartzite (5788) shows a lineation parallel to the dip within the bedding, and this is probably due to bedding plane slip.

Cleavage is well developed in most of the argillaceous rocks. Close to the axial planes of minor folds it is parallel to the axial plane as shown in Plate I, No. 5, but in many cases it is parallel to the bedding and thus is not useful in interpreting the major structure.

Faults are particularly numerous in this area as in all other Precambrian areas so far examined in Tasmania. The most important is the Donaldson River Fault which extends from south of Conical Rocks for at least 10 miles N.N.E. across the Pieman and up the Donaldson River. There are two other faults between the Donaldson and the Interview Rivers and one along the Interview itself and all have approximately the same direction (N.E. to N.N.E.). There is another set of faults which trend N.W. but these are only of minor importance. The Donaldson River Fault may have a considerable throw while the N.W. trending faults have movements in the order of tens of feet. A third set of minor faults trends almost east-west.

Regional Metamorphism

Most of the sediments show the effect of a low-grade regional metamorphism which reaches only chlorite zone (muscovite-chlorite subfacies of the greenschist facies). The rocks along the north Pieman Head contain biotite but this is probably due to the close proximity of the granite. The shearing stress factor was apparently high in some places particularly along the coast where the quartzites show granulation and the conglomerates contain deformed pebbles. The grade appears to rise to the east of Corinna as coarse phyllites and schists occur several miles up the Pieman to the east and south-east.

Thermal Metamorphism

The granite shows thermal effects on the sediments along its margin but the metamorphism is most marked along the eastern boundary where it is in contact with the Interview Beds. The phyllites on the north bank of the Pieman, east of the contact show progressive changes towards the granite. Within about half a mile from the contact, the phyllite changes from a normal low grade regionally metamorphosed rock containing quartz, muscovite, magnetite, tourmaline and rutile into a spotted phyllite as tiny clots of chlorite develop (5764, 5766, 5767, 5768). The grainsize and diameter of the spots increase in size slowly until immediately next to the igneous rock is found a dark-grey hornfels (5770) in which the cleavage has been obliterated by recrystallization. It is coarser than the spotted phyllites and contains ragged quartz and poikiloblastic plates of muscovite with biotite, acid plagioclase and magnetite.

The sediments on the south side of the Pieman Heads strike parallel to the coast and almost at right angles to the margin of the granite, Plate I, No. 6. A band of black slate (5816) once again shows the effect of the superimposition of a thermal metamorphic texture on a regional schistosity. The faint cleavage at an angle to the bedding has been almost obscured by recrystallization. The rock is black, fine-grained, and consists of quartz, muscovite and biotite, with very abundant pyrite. Andalusite porphyroblasts up to 1 cm. long, elongated parallel to the cleavage, are visible in the hand specimen; in thin section the andalusite shows the typical cruciform structure of chiastolite.

Some quite striking spotted hornfelses (5782, 5826, 5822, 5828) occur near the granite contact. These are medium-grained and light-pinkish grey in colour with irregular pink spots which are usually a millimetre or two in diameter although some range in size up to 1 cm. across; they consist of quartz, muscovite and untwinned feldspar (albite?) with biotite, zircon, rutile, pyrite, sphene and tourmaline while andalusite occurs as porphyroblasts. The spots usually consist of an aggregate of tiny grains of andalusite or less often of muscovite.

There is a mass of altered dolerite (1783) in a cove about half a mile east of the South Pieman Head contact. The basic rock was originally regionally metamorphosed to a schistose amphibolite similar to the other members of the dyke swarm described previously, but it was then thermally altered. It consists of bands of green hornblende intergrown with brown biotite alternating with bands of quartz and dusty feldspar. Ilmenite is surrounded by growths of amphibole. The random growth of the ferromagnesian minerals under thermal metamorphism has tended to obscure the schistosity although much of the formation of the new minerals was in an anisotropic medium and followed the original schistosity.

The thermal metamorphism has not been intense and probably only represents the actinolite-epidote hornfels subfacies of the albite-epidote-amphibolite facies although it is possible that the amphibolite facies is reached immediately next to the contact.

Cambrian Ultrabasic Rocks

There are large masses of ultrabasic igneous rocks in the area around Bald Hill and the Heazlewood River. The most important rocks are pyroxenites with lesser peridotites and serpentinites and these are cut by small bodies of albite-rich basic and intermediate rocks. There has been considerable mineralization in this area and a number of interesting minerals were found.

The Bald Hill pyroxenite is a medium to coarse-grained enstatolite consisting chiefly of enstatite with a little fresh olivine. There has been slight serpentinization, chiefly of the olivine.

On Heazlewood Hill are pyroxenites, peridotites and serpentinites which have been cut by a small dyke of albite syenite. This rock consists of ragged pale blue-green hornblende and tabular albite. The plagioclase, many grains of which have an outer zone of fresh clear albite, is twinned on combinations of the Albite and Carlsbad laws and is obscured by a sericitic alteration product. There is a little clinozoisite and chlorite present.

Introduction of copper and lead is shown by the presence of primary bornite and galena, and oxidation products include malachite and azurite.

A specimen of pyroxene found associated with the pyroxenite at Heazlewood Hill shows a most unusual habit. It is white and translucent, contains small tabular inclusions of chlorite, and has a markedly tabular form due to strong elongation parallel to the *c* crystallographic axis. The identity of the mineral was established by X-ray and optical procedure, and it is being studied further by R. J. Ford.

Devonian Granitic Rocks

Apart from the major granite mass of the Meredith Range which lies to the north-east of the area and was not investigated, the granitic rocks are restricted to the coastal area. The most important is a thick, curved, dyke-like body which extends from the mouth of the Pieman River up to Sandy Cape. It is 18 miles long and about three miles wide at its thickest part and lies along a faulted anticline between the Interview Beds and the Rupert Beds.

The granite (5859) is light-coloured and coarse-grained with abundant large phenocrysts of feldspar, and consists of orthoclase, quartz and biotite with a little plagioclase and muscovite. The orthoclase is perthitic and contains disconnected patches of plagioclase which are in optical continuity with each other; this suggests that the granite has been formed from a granodiorite by potash metasomatism. Investigation of the Coles Bay Granite indicates a similar genesis and the significance is now being studied.

The plutonic rocks as well as the surrounding hornfelses are cut by sporadic dykes of aplite and pegmatite which are often rich in columnar tourmaline.

The granite has been sheared in two places, viz., just east of the hut on the Heads, and a short distance west of the granite contact on the south side of the Heads. The granite is brecciated and sheared with the development of a very irregular, almost gneissic, texture (5769). In a thin section the quartz, with its cracks and undulose extinction, and the broken-up and sericitized feldspar reveal evidence of great stress. The large fragments are set in a finely-grained schistose matrix cut by thin veins of chlorite.

The shearing of the granite is restricted in area and probably lies along faults.

TERTIARY SYSTEM

The Precambrian sediments are overlain unconformably by a thin discontinuous formation consisting of siliceous quartz conglomerate with some breccia. The conglomerates vary in grainsize down almost to sand grade but the majority of fragments are an inch or more across. The greatest thickness noted was about 10 feet. Chief occurrences are on Long Plains and Brown's Plains and along the track from Corinna to Zeehan. There is an extremely small patch of weathered olivine basalt of presumed Tertiary age resting on the conglomerate at Brown's Plains. The formation will be named the Brown's Plains Conglomerate and is defined as that siliceous rudite on Brown's Plain overlying unconformably the Precambrian sediments and lying below the olivine basalt. It is unfossiliferous. The sediment is notable because of its strong siliceous cement and consequent hardness which is unexpected in such young sediments. The rocks (5798, 5799) are usually composed of well-rounded fragments (less often of angular

particles) of quartz and quartzite showing a high sphericity together with a little feldspar, tourmaline and apatite. A thin section shows that the cement is unusual. The quartz grains are surrounded, first by a layer of clear quartz in optical continuity with the core, followed by common opal showing colloform texture. A little chalcedony fills the remaining cavities. Twelvetrees (1903) reported that economically valuable deposits of alluvial gold was associated with this conglomerate.

Similar siliceous sediments occur also in patches along the north-west coast stretching from the Black River to Deloraine. In some cases they are associated with Tertiary basalts but often the basalt is absent. It may be possible that the silification was caused by meteoric waters during a period of abnormal climate early in the Tertiary. It seems more likely, however, that the silification was due to the presence of overlying basalt which has now been partly or wholly removed by erosion. It is presumed that the molten basalt flowed over water-charged gravels and that the resultant steam which would be superheated and under considerable pressure dissolved some silica and then deposited it as a cement on cooling. The nature of the deposited silica changed from quartz to the lower temperature hydrous forms, opal and chalcedony, as the temperature fell. Part or even the whole of the silica may have been derived from the overlying basalt as siliceous residual fluids formed during consolidation. It is interesting to note that there are thick opal-chalcedony veins cutting the Tertiary basaltic breccia at Sandy Bay, near Hobart.

QUATERNARY

There are unconsolidated gravels and pebble beds on the elevated plains near the coast. These are of unknown age and may actually be as old as Tertiary. They may represent the unconsolidated marine and terrestrial equivalents of the Brown's Plains Conglomerate. These are discussed more fully in the section on geomorphology (Twidale, this volume). The high level fluviatile boulder beds above river level at Corinna are also dealt with in that section.

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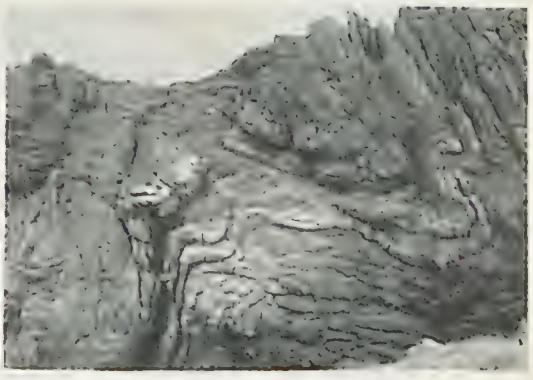

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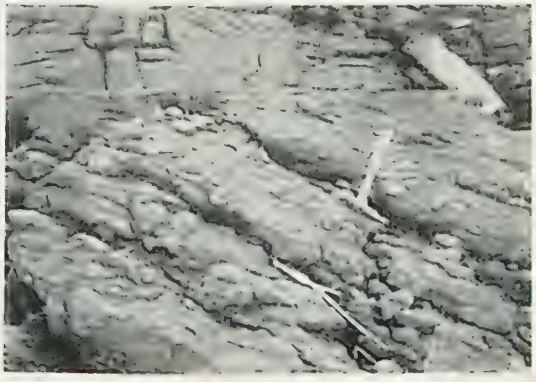

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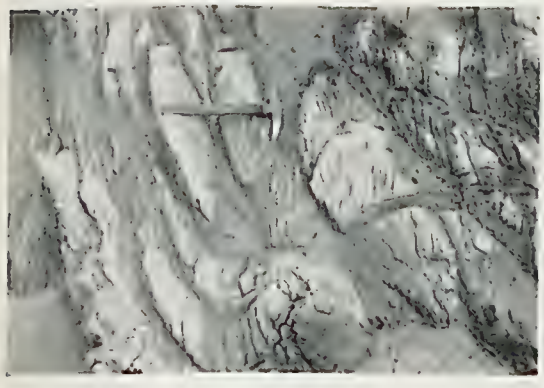

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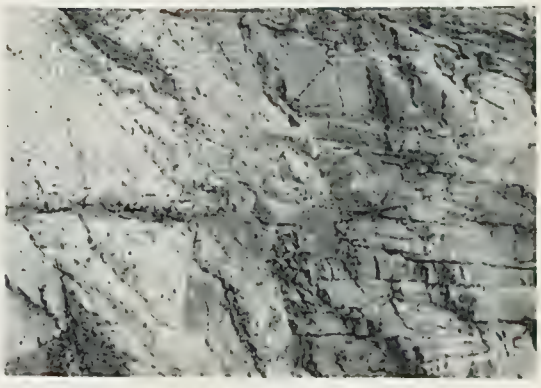

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Nos. 1 and 2.—Strongly contorted and overturned quartzites and phyllites of the Rupert Beds.
No. 3.—Sheared conglomerate in the Rupert Beds.
No. 4.—Quartzite conformably overlying conglomerate in the Rupert Beds. The cleavage which is at an angle to the bedding is well developed in the matrix of the conglomerate but only poorly in the quartzite. Some pebbles are elongated parallel to this cleavage.
No. 5.—Phyllites south of Rupert Point showing axial plane cleavage.
No. 6.—Strongly discordant contact between hornfelses and granite south of the Pieman Heads.

A RECONNAISSANCE OF THE CORINNA-PIEMAN HEADS AREA—GEOMORPHOLOGY

By

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(With 4 Text Figures and 2 Plates)

(*Communicated by K. D. Nicolls*)

INTRODUCTION

The area with which this paper is concerned largely comprises a plateau of mature, moderately low relief, the level of which gradually falls to the west, and which terminates on the seaward side in a steep scarp slope. At the foot of this scarp is situated a small and much dissected bench and slightly below this again is a coastal zone, consisting mainly of rocky headlands and sandy bayhead beaches but also, in places, containing dunes and alluvial flats. Traversing and draining part of the area is the Pieman River which, quite apart from being the largest river of the area under consideration is one of the major water courses of Tasmania.

The area surveyed is indicated in figure 1, a location map of the area, and this report is the result of a brief period of field work during which traverses were made of typical sections of country, and examination made of the various geomorphological units as determined by previous photo-interpretation of aerial photographs. The units have been mapped upon aerial photographs but there is a certain amount of ground survey information available (Nicolls, K. D. and Taylor, R. personal communication), and full use has been made of this.

Much of this paper is occupied with the features displayed within the actual survey area, but there are several pertinent and relevant phenomena to be observed just outside this limited area and these are cited as evidence where suitable and necessary.

GENERAL GEOMORPHOLOGY

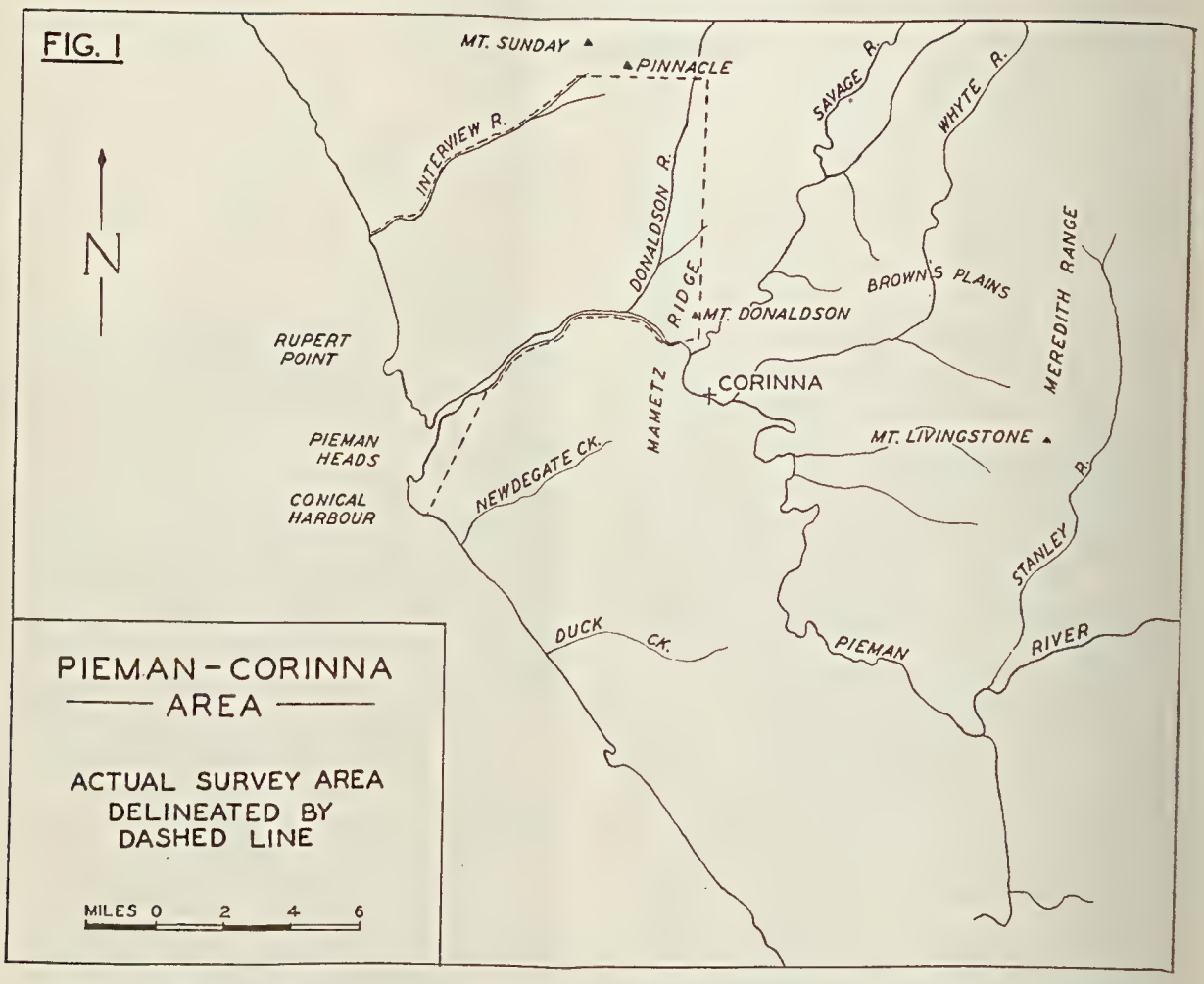
The Pieman-Corinna area has been subdivided into three geomorphological units, a plateau, bench, and coastline, each of which transgresses geological boundaries; and the two major stratigraphic units the Pre-Cambrian metamorphics (comprising quartzites, conglomerates, phyllites, and hornfels) and the granite, which intrudes the metamorphics, both appear in each of the major geomorphological units. Erosion surfaces are clearly of importance in this area, whilst structural control of relief is of secondary significance, a factor which renders the area all the more interesting. The plateau is an undulating or gently rolling surface extending from approximately 250 to 900 feet above mean sea-level; protruding above the general level of the plateau are various residual remnants such as Mt. Sunday, Mt. Norfolk (2600 feet), Mt. Hadmar (2500 feet) and Mt. Vero (2300 feet), and to the east, at a height of some 900-1000 feet, the plateau gives way to the rugged high peaks of the Meredith Range.

Deeply incised in the plateau is the Pieman River which flows in a gorge, the sides of which become less precipitous towards the sea. The river is exceptionally deep, being of the order of 90 feet in its lower reaches, and at Hell's Gates the channel has never been bottomed despite a sounding of 130 feet. The deep channel continues for some 12 miles upstream from Corinna and here there are rapids in the vicinity of which the river quickly shallows to four or five feet; but above the rapids the trench-like form of the channel is maintained. A tidal effect is felt at least as far upstream as Corinna where the range is of the order of two feet. However, the river is unnavigable because of a recently formed wave-constructed bar at its mouth. (In the latter part of the last century steamers did penetrate a considerable distance up the Pieman and in one of the tributaries of the river the wreck of one such ship remains.)

The general course of the Pieman within the area considered herein is east-north-east to west-south-west, and in its lower reaches, at least, the channel follows the strike of the metamorphics for considerable stretches. On the whole the river widens gradually towards the mouth, but there is a considerable constriction at Hell's Gates where the river crosses resistant quartzite strata which cause the channel to narrow to less than 100 yards. Just to the east of Hell's Gates is a well-formed intrenched meander in which the absence of a pronounced slip-off slope is noticeable.

Compared with the Pieman all other streams of the area are minor; they follow the regional slope of the area and flow from east-north-east to west-south-west giving a good parallel drainage pattern, though in detail structural effects (e.g., angular patterns) are discernible.

The general physiography is illustrated in fig. 2, a much generalised block diagram of the area, and in fig. 3 cross sections, of which the locations are indicated in fig. 4, are presented. Various aspects of the geomorphology of the area are illustrated by photographs included at the end of this paper.



GEOMORPHOLOGICAL UNITS

These are indicated in fig. 4 and it will be noted that some reliance has been placed upon map notes to show the occurrence of some of the smaller units.

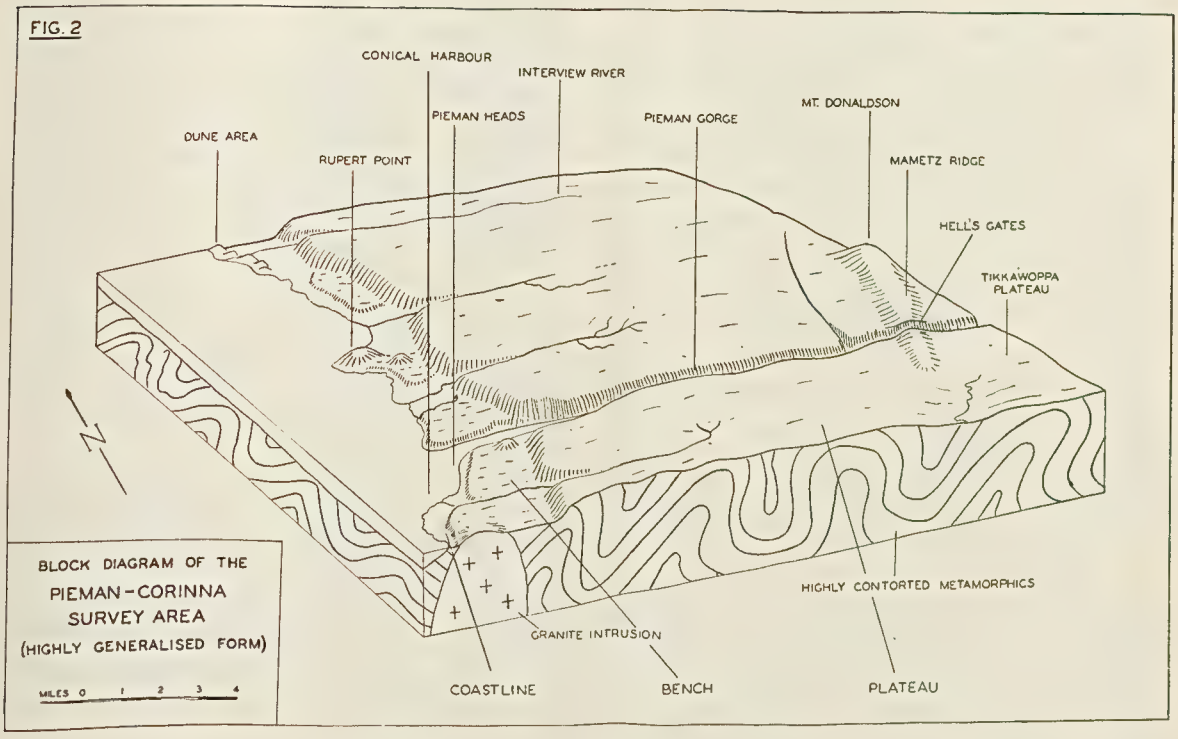
1. The Plateau

(A) This low rolling area has only a moderately low amplitude of relief and extends from 250 feet above present sea-level near the coast to over 900 feet inland where it is known as the Tikkawoppa Plateau. Over the greater part of its area the plateau is developed upon metamorphic rocks.

Away from the coast the valleys are shallow and marshy but nearer the scarp the streams have been incised and the valleys are deep. A general east-north-east—west-south-west parallel pattern predominates, but areas of angular pattern following joints in the metamorphics and granite are not uncommon, and in granite areas a rectangular pattern is occasionally evolved. The intensity of the drainage lines is not great except where a close structural control has been exerted.

Because of the heavy rainfall received by the area and the impermeable nature of the quartzites and other metamorphics which form the country rock, all but the steepest slopes are marshy and support only a button-grass vegetation; the well-drained sides of the incised stream valleys carry a dense scrub and tall timber vegetation as do also a large number of parallel ridges which trend north-north-east—south-south-west; these ridges are basic dykes intruded in the metamorphics, possibly along joint or strike lines. (See section on Geology.)

The surface of the plateau is scattered with well-rounded or ovoid white quartzitic pebbles averaging two inches, but attaining eight inches, in diameter. In addition to those exposed, the pebbles are often found abundantly beneath the soil surface. (See



section on Soils.) The pebbles are relatively few in number near the coastward or lower end of the plateau, but at an elevation of about 400 feet they occur in profusion, especially on small narrow benches or platforms which are cut in hill slopes and which as far as the eye can judge occur at a constant level. These benches, being pebble strewn, are considered to be terraces, which (see later) are thought possibly to be former beach terraces, and in the remainder of this paper they are referred to as such. Along the Waratah Highway, a few miles north-east of Corinna, these rounded quartzitic pebbles are well exposed and in places attain thicknesses of five or six feet. Frequently the pebbles have filled irregularities resembling potholes in the underlying metamorphics and at certain places the pebble layers can be seen intercalated with peaty soils—two peats between three gravel beds. It is important to mention that these phenomena—interbedded pebbles and peat, and pebble-filled potholes—do occur and have been observed on stream divides: this factor is significant in considering the origin of the pebbles, which will be discussed later.

The general low relief of the plateau is broken by Mt. Donaldson which attains a height in excess of 1400 feet and which rises abruptly from the plateau; the Mametz Ridge is a south-south-west continuation of the mountain and is caused by the same resistant quartzite strata which give rise to Hell's Gates.

On its coastal side the plateau terminates in a steep scarp some 180 feet high in which rock outcrops are common; in granite areas great tors and rectangular blocks are striking features. In the north the scarp is impinged upon by the shifting sand dunes of the coastline, and in the south the granite intrusion of Conical Harbour forms a resistant mass so that the plateau, with only a slight amount of dissection and truncation is there preserved and reaches the sea.

(B) The general form of the plateau is that of a late-mature surface, i.e., one of low, broadly undulating relief, and since uplifted. Whether or not the feature should be termed a peneplain depends largely on which authority one chooses to follow: if one relies for instance upon Wooldridge and Morgan (1937) then the plateau is not a peneplain (because only a very few miles inland the surface of low relief gives way to the rugged Meredith Ranges) but is a partial peneplain or a "strath" in the connotation of several writers of whom Shaffer (1946) may be given as a recent example. A strath is a plain of erosion of limited areal extent developed during an epicycle of erosion.

If, on the other hand, one prefers the viewpoint of Johnson (1919) for example, then it is quite valid to regard and term the plateau surface, limited in area as it is, as a peneplain which has been uplifted. The present writer does not consider the area of the plateau surface to be sufficiently great to warrant the term peneplain, though it is

not thought necessary that a surface of low relief should extend over a whole continent or island before the term is utilised. For example, the "downs" area of north-west Queensland [See Twidale, C. R. Forthcoming reports on the "Geomorphology of the Leichhardt-Gilbert Area" (N.W. Queensland).] is considered to be a peneplain for it does extend over many thousands of square miles, yet to either side upland areas occur.

Since the plateau surface is not considered to be that of an uplifted peneplain it follows that the residual remnants such as Mt. Donaldson, Mt. Sunday and Mt. Norfolk cannot, by definition, be termed monadnocks, though it is to be emphasised that they are essentially of a similar residual nature.

Furthermore, as is mentioned above, the plateau surface should not be attributed to a cycle of erosion but to an epicycle, or a cycle which has been interrupted before completion was attained. The intrenched meander with no slip-off slopes located on the Pieman and referred to earlier was possibly inherited from the surface of low relief associated with this epicycle.

The widespread distribution of the pebbles on the plateau surface indicates that they were deposited during or after the erosion of the surface; the occurrence of the pebbles on divide and in valley depression alike suggests that they are not fluviatile in origin for streams could not attain such a wide spread of pebbles in an area of low rolling relief. However, E. S. Hills (personal communication) has directed to the attention of the writer Victorian examples of rounded gravel with which is associated alluvial gold, widely spread over rise crests and local divides, and whose fluviatile origin is beyond doubt. Also, J. N. Jennings (personal communication) has pointed out that statistical evidence concerning the degree of roundness and size composition of the quartz pebbles would be required before any more definite opinion could be given as to the origin of the gravels. A. Spry (personal communication) suggests that the higher level gravels of the Brown's Plains area are of definite non-marine origin, whereas the lower level gravels situated nearer to the present coast may conceivably be of marine origin; and K. D. Nicolls (personal communication) who has had the benefit of a further examination of the gravels of the Brown's Plains area is also of the opinion that they are of non-marine origin. There appear to be four possibilities: viz., that the gravels are of (1) marine, (2) fluviatile (3) fluvioglacial or (4) glacial (sub-glacial or englacial) origin. The present writer would favour the first or third possibility, but in the absence of palaeontological evidence no positive conclusion can be reached.

The 400 foot level, with its well-defined terraces, which are interpreted as beach terraces, appears well represented, and though palaeontological evidence is again desirable, may be accepted at this stage. If there were a period of higher sea-level than at present, then, during this period of submergence of the land, material was doubtless carried down the sub-marine slope and deposited in irregularities on the surface and indeed covered much of the former land surface with a veneer of debris. Such a postulate might well explain the pedology of the plateau area.

There is no evidence to indicate that the suggested relative changes of sea-level were accompanied by any deformation of the land and it is not unreasonable to conceive that the changes

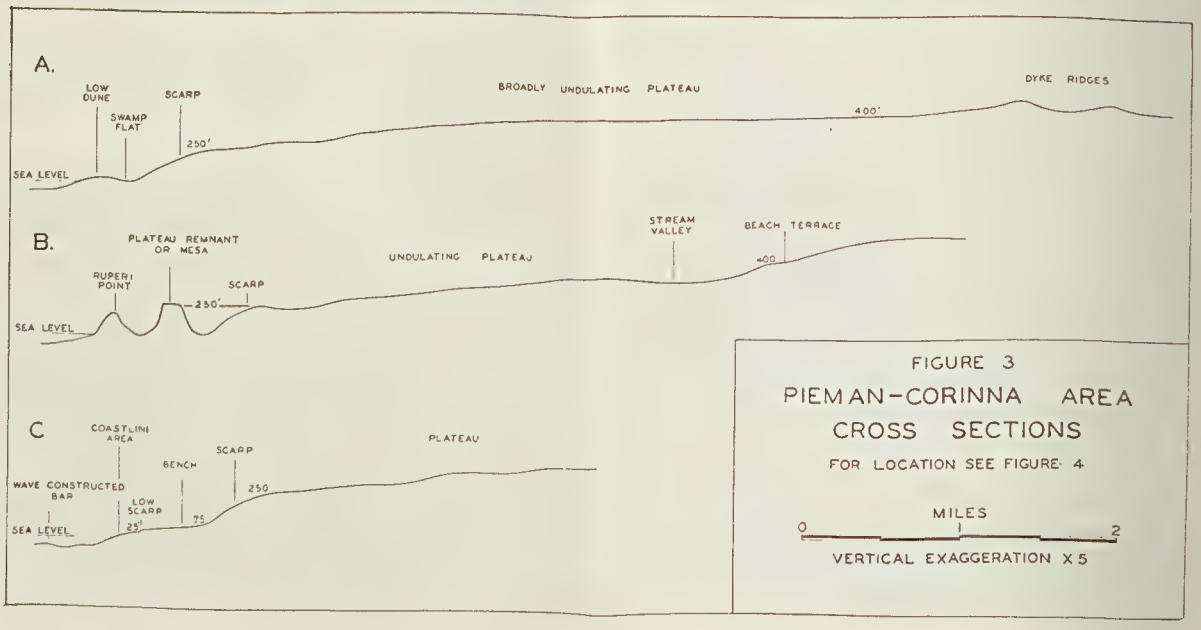


FIGURE 3

PIEMAN–CORINNA AREA

CROSS SECTIONS

FOR LOCATION SEE FIGURE 4

MILES

0 2

VERTICAL EXAGGERATION X 5

were eustatic in nature. It may seem unlikely that sea-level should formerly have attained such heights above its present level but benches related to movements of a eustatic nature which occur up to 650 feet above present sea-level were implicated in the writings of Wooldridge and Linton (1939), Sparks (1949), Brown (1950) and Balchin (1952) regarding Pliocene or Pleistocene* sea-levels in Southern England, and in those of Coleman and Ferrar (1954) concerning similar features in the North Boulonnais of France. It is certain that verification by fossiliferous evidence is required before any assertions can be made either in Western Tasmania or elsewhere, but "coastal or estuarine gravel-terrace at from 100 to 150 feet . . . in various parts of Tasmania" are noted by David and Browne (1950, p. 600), and the definite possibility of eustatism should be borne in mind, for writing of the detailed work in East Kent and

* The precise dating of the levels is in some doubt at present, but the general tendency in England appears to be to extend the Pleistocene at the expense of the Pliocene; see for example King and Oakley (1949), Baden-Powell (1950), Zeuner (1950) and Boswell (1952).

FIGURE 4.

PIEMAN–CORINNA AREA

WESTERN TASMANIA

GEOMORPHOLOGICAL UNITS

- Ia UNDISSECTED PLATEAU
- Ib IMMATURELY DISSECTED PLATEAU
- 2 BENCH
- 3 COASTLINE

COUNTRY ROCK PRE-CAMBRIAN METAMORPHICS EXCEPT WHERE OTHERWISE STATED.

MILES

South East England as a whole, Coleman and Ferrar (*op. cit.*, p. 67) state: "Here the agreement between various workers is sufficiently great for general acceptance of the eustatic hypothesis". If eustatic features are present in Southern England then they should be present in other parts of the world, and their presence in Australia is not beyond the bounds of possibility.

2. The Bench (See figs. 2 and 4)

(A) Ranging in height between 25 and 70 feet above sea-level the bench is well preserved around the Pieman mouth where it is an undulating area drained by marshy streams. Elsewhere the bench has been extensively dissected and reduced to an area of very low relief; only small residual areas remain, and where granite outcrops, typical low whalebacks occur. Coastal dunes some 30 feet high have impeded drainage and caused the lower lying areas to be converted into swamps. Streams eating back into the terrace have given rise to deep valleys in marked contrast with the shallow marshy valleys of the terrace proper, and the junction of the two valley stages is frequently marked by falls or rapids which may be regarded as nick-points.

The bench area occurs as a purely coastal phenomenon, and does not penetrate up the river valleys for any distance. The streams of the bench have eaten back into the plateau and where the profiles of these more active streams join those sluggish streams of the plateau there is a marked break of slope. Isolated remnants of the plateau remain as mesas and hills within the bench area.

As has been previously mentioned, the plateau, for structural reasons, reaches the coast in the south of the area; in the north the bench is covered by coastal dunes some 200 feet in height which have encroached inland as far as the plateau scarp. These features are shown in figure 3.

(B) Because of its essentially coastal distribution and its constantly narrow width it is difficult to conceive of the bench originating in a way other than by the action of waves eating into the seaward edge of the plateau. In other words it is regarded as being essentially a marine bench which has suffered uplift and dissection by streams. Despite searches at likely places, no geological evidence for the marine origin of the beach has been found.

It is postulated that the carving of the bench followed a lowering of the sea, or rise of the land, of some 180 feet, when the surface of low relief became a plateau. Subsequently, sea-level fell further by some 45 feet, and it was during and after this emergence of the land that the uplifted bench was dissected.

3. Coastline

This unit forms a narrow zone at the coastal periphery of the area surveyed and for the most part comprises rocky headlands and bay-head beaches, the beaches being composed to some extent of material derived from the wearing back of the headlands. Below the beach and to seaward of the headlands a low-level marine bench (as opposed to the high-level one which has been dissected) carved in solid rock is frequently observable.

Off-shore stacks are not infrequent and structural effects are well displayed; strike lines have been well-exploited by wave action and small dolomitic exposures are characteristically fluted. Coastal granite gives rise to spectacular tors and rectangular blocks. On the south side of the Pieman mouth and also in very narrow zones up the river, are small areas of flat and marshy alluvium, and along the coast in the north of the area is an extensive area of drifting dunes, the dunes being over 200 feet high in places and continuing for many miles up the coast. Dune formation on the coast has caused impedance of drainage on the dissected terrace areas behind the dunes and swamps have developed.

GEOMORPHOLOGICAL HISTORY

From correlation of the evolution of each of the major geomorphological units, the following sequence of events for the whole area can be deduced:—

1. The reduction of the area to one of low relief: a mature stage of the fluvial cycle of erosion was attained, with some remnants of circumdenudation left.

2. Marine incursion to the present 400 foot level during which the beach-terraces were formed.

3. The recession continued until there was a further and quite long pause at the present 70 foot level: marine planation of plateau edge occurred, forming a marine bench and cliff.

4. Further fall in sea-level, during which the marine bench was relatively raised and dissected: dunes formed on the coast, drainage was impeded, and swamps formed.

This sequence seems to be fairly well substantiated but only tentative suggestions can be made as to the dating and explanation of the events. In attempting this dating, evidence from other areas as well as the data from the Pieman area will have to be considered.

Dealing with local facts first, the plateau in the Brown's Plains area is overlain by basalt. Clearly the surface must pre-date the basalt but the age of the basalt is not known. Local opinion (Hills and Carey, 1949) considers all the basalts as being no older than Pliocene, and while there may be Pleistocene eruptions there is no evidence for them; later opinion (David and Browne *op. cit.*,) regards the basalts of the Wynyard-Waratah area to be of Pliocene age, and those of the Waratah area to be Eocene. Spry (personal communication) considers the basalts to be of approximate Miocene age and this opinion is here accepted as a basis on which to work: should later studies demand a change in the age estimate, then the ages of the physiographic events which date from the extrusions can be revised accordingly.

Turning to broader considerations, there is first the widely distributed and well recognized Cretaceo-Tertiary erosion surface which acts as a convenient time marker in many parts of Australia. Another, but less definite time marker is a Miocene period of disturbance during which, in the opinion of some, Tasmania became separated from the Mainland by the formation of a rift valley which the Bass Strait now occupies, and when the west coast of Tasmania was formed by north-south faulting. However, Professor E. S. Hills (personal communication) points out that Victorian geologists have long been of the opinion that the Bass Strait is a much more ancient feature, and that it has been, throughout Tertiary time at least, a major earth feature. In view of this, no weight should be attached to this possible time marker, though the west coast can still be a fault coast of Miocene age.

There is also the problem of a marine incursion to the present 400 foot level: in Europe and recently in Western Australia (Clarke and Phillipps 1953), benches thought to be of marine origin have been related to late Tertiary and Pleistocene oscillations of sea-level and in Europe to isostatic depressions due to ice sheets.

Thus there is a framework into which the events discernible in the Pieman-Corinna area can be fitted.

In the first place the plateau must pre-date the basalts and thus is probably of pre-Miocene age. It is not considered that the plateau comes within the range of the Cretaceo-Tertiary planation for it is firmly considered that the surface of this age is one of the higher levels of Central Tasmania and not this small surface which can only be attributed to an epicycle of erosion which followed the interruption of the main early Tertiary cycle. This consideration precludes a pre-Eocene age of the surface and one is left with a pre-Miocene age for it. Such an age would comply quite well with the concept that the west coast of Tasmania is a Miocene fault coast—the epicycle of erosion fits into late Miocene-early Pliocene times and was interrupted in the late Pliocene by the extrusion of basalts and later by extensive oscillations of sea-levels. Thus if a Miocene-Pliocene age is postulated for the plateau surface the later marine incursion, during which the 400 foot terraces were developed, becomes a Pleistocene event.

There followed further falls in sea level during which the plateau was dissected, the lower bench was formed, and the present coastline developed. This constant, though discontinuous, fall in sea-level recalls the staircase of benches described by Brown (*op. cit.*) from Cardiganshire in Central Wales: these features he considers to be related to a pulsatory negative movement of sea-level (*Ibid.*, p. 65).

The features and events are tabulated in Table I, and the following evolutionary story can be unfolded.

During early Tertiary times, much of Tasmania was reduced to a peneplain which, after suffering relative uplift, perhaps accompanied by faulting on the west coast, was subjected to peripheral dissection and planation. On the west coast of the island, a small plain of low rolling relief, above which protruded remnants of circumdenudation was formed; on this plain consequent streams developed and some of the latter, including the Pieman, developed meandering courses. The plain was backed on the inland side by rough and rugged mountains such as the Meredith Range.

Then followed a rise in sea-level up to the present 400 foot level (the then 150 foot level) when small beach terraces were formed. Further recession occurred and there was a considerable pause at the present 70 foot level during which the edge of the plain suffered marine planation. This stage of sea-level must have been of considerable duration for a marine bench of some width was formed.

Gradual uplift of the land caused the emergence of the marine bench which was subjected to subaerial denudation. However, dune formation on the coast caused the impedence of drainage and swamp formation. There followed further emergence and the formation of another, smaller, marine bench.

CONCLUSIONS

The foregoing is a record of a brief reconnaissance survey of a small area of north-west Tasmania and, as always, several problems and relationships remain to be solved. For example, the relationship of the plateau of the Pieman-Corinna Area with the Henty peneplain of the Queenstown area should be examined, and a correlation attempted between the 25-70 foot terrace and terraces in other parts of Tasmania, for instance old shore lines at 20 and 50-60 feet in the north-west of Tasmania and near Hobart (David and Browne 1950, p. 600, Spry, personal communication). The role, if any, of warping in the present physiography should be investigated and the nature and ages of the several features described in the previous pages should be determined if this is possible.

The Pieman-Corinna Area is a fine example of a landscape in which major features are due to past denudational events and processes rather than to structure. It is of considerable interest, and is significant in that the units discernible there extend to north, south and east, and thus the descriptions and suggested genesis of the units may be of value for future work.

ACKNOWLEDGEMENTS

This work was carried out in conjunction with the Victorian Branch of the Boy Scouts' Association during their camp at Corinna in January, 1954.

TABLE I

PERIOD	AGE	MOVEMENTS OF BASE-LEVEL	PHYSIOGRAPHIC HISTORY
TERTIARY	EOCENE		Planation of upper surface(s) of Tasmania.
	OLIGOCENE		(Tertiary faulting of west coast of Tasmania.)
			Dissection and planation of upper surface, with formation of high level plateau in Pieman-Corinna Area.
	MIOCENE		(Basalt extrusion in Waratah area.)
	PLIOCENE-PLEISTOCENE		(?) High-level beach formation and marine deposition.
		Rise in sea-level to 400 foot level	Beach formation.
		Fall in sea-level to 70 foot level.	Marine planation of edge of plateau; bench formed.
QUATERNARY		Further fall in sea-level.	Dissection of terrace, and formation of lower marine bench.
	RECENT		Dunes built; subsequent swamp formation.

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EXPLANATION OF PLATES

PLATE I

No. 1.—Coastline: extensive wave erosion along possible strike fault in highly inclined Pre-Cambrian metasediments.

No. 2.—Wave-cut terrace with scarp and plateau to right. At Pieman Heads.

No. 3.—Massive quartzites exposed in coastline. North of Conical Harbour.

No. 4.—Coastline: wave erosion along strike of relatively unresistant strata. North of Rupert Point.

No. 5.—Marine terrace from top of plateau residual; low residual hill in right middleground. South side of Pieman Heads.

No. 6.—Rectangular granite blocks in plateau scarp, north of Rupert Point.

No. 7.—Marine terrace, with plateau above. Residual mountain standing above plateau in far distance.

No. 8.—Plateau residuals standing above level of marine terrace at Rupert Point.

PLATE II

No. 1.—Gorge of Pieman River.

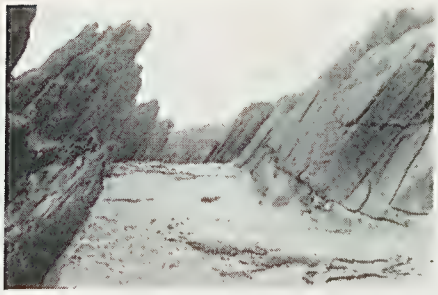
No. 2.—Gorge of Pieman River. Plateau seen in background.

No. 3.—Landslide on side of Gorge of Pieman River.

No. 4.—"Button-grass plains." Plateau top, with Mt. Donaldson, monadnock-like residual, on skyline.

No. 5.—Mesa-like plateau remnants at Rupert Point.

No. 6.—"Button-grass plains" on top of plateau.



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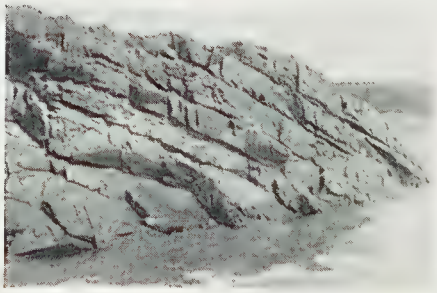

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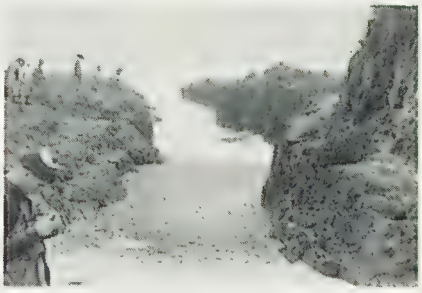

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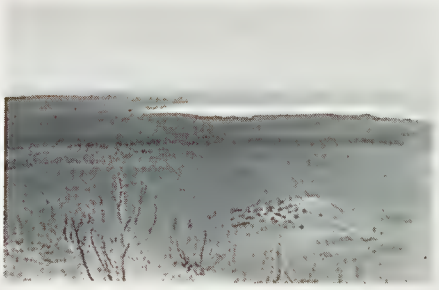

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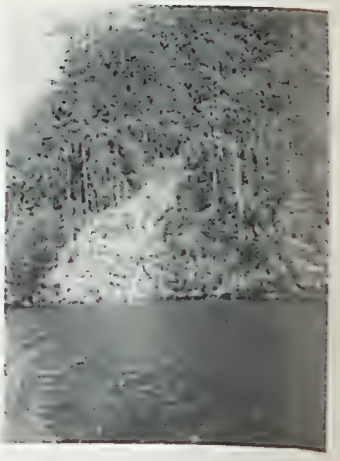

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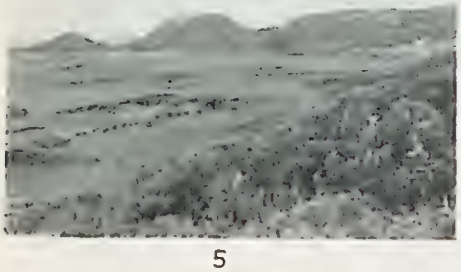

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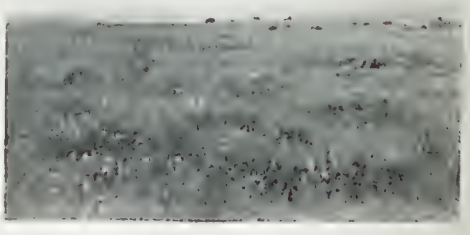

6

A RECONNAISSANCE OF THE CORINNA-PIEMAN HEADS AREA, TASMANIA—SOILS

By

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ABSTRACT

The climate of the Pieman Heads district is wet and cool enough for formation of acid peat soils (moor podzol peats) in extensive areas of restricted drainage and button grass vegetation. Under timber the soils are better drained and less organic. Morphological descriptions and analytical data are given for the peats. The sand dunes along the coast between the Interview and Lagoon rivers are mostly young and contain appreciable carbonate (shell fragments) but some are old enough to have developed groundwater podzol profiles. The agricultural potentialities of the area are slight.

INTRODUCTION

In connection with an expedition of Victorian Boy Scouts to Corinna in January, 1954, the soils of the area were examined along the Waratah Highway between Long Plains and Corinna, and along two reconnaissance traverses based on the Scout camp at Rupert Point. The first of these traverses was along "Bulman's Track" from Pieman Heads to the Interview River, with several short side-traverses; and the second from Pieman Heads passing one to two miles to the eastern side of the timber belt between the Pieman and Interview rivers, crossing the Interview river three miles inland and thence to the coast via Bulman's mine workings. The coast itself was traversed between the Interview and Lagoon rivers, where sand dunes extend up to a mile inland. Reference may be made to the map in the accompanying paper on geology by Spry and Ford.

Aerial photographs were used in the field, and for interpretation in the laboratory. Soil samples from two profiles sampled by the normal procedure from pits, and 17 samples collected from auger borings, were examined by routine methods in the laboratory.

The geomorphic units of the Pieman Heads area described in the accompanying paper by Twidale, persist northward beyond the Arthur river. The soils and geomorphology of this coastal belt between the Lagoon and Arthur rivers are the subject of another report (Nicolls 1955). The "peneplain" described therein is a continuation of the "plateau" of Twidale's paper, and its peaty soils are similar to, though rather less organic than, those near Pieman Heads.

CLIMATE

The following information is extracted from published (1936), and unpublished data of the Hobart Meteorological Bureau.

A station at Pieman Heads recorded rainfall in the years 1918-1940, during which time the average annual total was 53·3 inches . From this and limited other data, it is probable that rainfall on a strip of country two or three miles wide along the coast from the Pieman northward to the Arthur river averages between 35 and 55 inches per annum, with the northern end rather drier than the southern and the coastal fringe considerably drier than the inland side. The ranges which run parallel to the coast six to eight miles inland greatly increase the precipitation so that Balfour eight miles inland and Corinna seven miles inland have annual rainfall averaging 77 inches and 72 inches* respectively. These figures are all from old records, as there are no stations now recording in the area. At Waratah, 27 miles N.E. of Corinna, elevation 2000 feet, rainfall in the standard period 1911 to 1940 averaged 87·1 inches per annum. The monthly distribution of rainfall at Pieman Heads is given in Table I. About three inches of rain falls in each of the five driest months.

TABLE I

Monthly Distribution of Rainfall at Pieman Heads, Inches.

(No. of Years: 22)

January	2·89	July	5·90
February	2·87	August	6·56
March	2·95	September	5·21
April	4·65	October	4·53
May	4·94	November	3·46
June	5·94	December	3·32

Average per year 53·3

Temperature data for the area are meagre but Cape Sorell, on the coast 40 miles south of Pieman Heads has a mean annual temperature of 54°F, with a mean maximum of 65° in February and a

* Figures for rainfall given here are averages for the actual years of record, and in the case of Balfour and Pieman Heads are close to the values corrected to the standard 30 year period 1911-40. For Corinna however, the corrected figure would be approximately 82.

mean minimum of 45° in July. Limited data from Marrawah three miles inland from the coast at a point 50 miles north of Pieman Heads, indicate that this station has about the same summer temperature as Cape Sorell but is about 2° colder in winter. Temperature in the Pieman Heads area is probably intermediate. The area is exposed to the drying effect of the prevailing strong westerly winds but cloudy overcast conditions are general.

SOILS

(*a*) *General.*—The climate is wet and cool enough for peat formation and on the plateau with its highly siliceous parent materials and drainage restricted by low slopes and by growth of button-grass, (*Gymnoschoenus sphaerocephalus*) most of the soils conform generally to Stephens' (1953) description of the rather varied group of Moor Podzol Peats. Deeper weathering of granite, with growth of timber vegetation, freer internal drainage and greater evapotranspiration lead to less organic soils in the timber belt between the Pieman and Interview rivers. The sand dunes, even where stabilized are mostly young enough to have retained shell fragments despite the severe leaching. The drifting sands are highly calcareous. One stabilized dune however is old enough to have developed a groundwater podzol profile. The terrace remnants between the coastline and the plateau are of small extent along this part of the West Coast, and the soils on them were not examined.

(*b*) *Button-grass Peats.*—Most of the soils of the non-timbered parts of the plateau belong to this group. They are alike in restricted drainage and a surface accumulation of peat, but the lower horizons and depth of the profile vary somewhat with the parent material. The mineral matter is usually fine sandy, coarse sandy or gritty, only a few profiles having much clay though occasionally there is a clay horizon. An organic hardpan, weakly to moderately cemented, is a frequent feature in the deeper profiles, contributing to the restriction of internal drainage.

In general the peaty surface horizon is black or dark brownish-grey, well humified, and about nine inches thick. The horizons below also contain appreciable organic matter and are grey-brown or darker in colour. The cemented organic pan if present is usually at depths between 24 and 36 inches and only a few inches thick, resting upon hard weathering rock, siliceous hardpan, or occasionally clay. In few profiles was it possible to bore with the soil auger deeper than 36 inches. Hardpans apparently cemented by silica were encountered in the gravelly deposits near Pieman Heads and in road cuttings of the Waratah highway six miles from Corinna.

Detailed descriptions of the two profiles sampled from pits are as follows. Profile H 72 differs somewhat from the generalised description above, in that it is shallower and consists entirely of peat over rock.

PROFILE H 71.

On a gently sloping surface of low relief, with restricted drainage. Elevation approximately 350 feet, on plateau alongside track 1¾ miles S.E. of mouth of Interview river (grid co-ordinates E 300800, N 876900). Button-grass dominant vegetation at sample site, with scattered small clumps of eucalypts nearby. Parent material granite, probably with some admixture of sandy marine sediments. Whole profile wet when sampled. Living roots concentrated in top foot but persisting in fair amount to 20 inches.

Horizon	Depth (inches)	Description
A_0	0	Black, coarse sandy peat, well humified, massive and coherent. Indistinct change to
A_1	6½	Brownish-black highly organic coarse sandy loam, massive and coherent, with 14% angular quartz grit. Indistinct change to
A_1	11	As above but lighter coloured and less organic, 2% grit. Fairly sharp change to
A_2	15½	Very dark brownish-grey slightly organic coarse sand with 6% grit, single grain structure, just coherent. Indistinct change to
A_2	19	Grey-brown slightly organic coarse sand with 9% grit, single grain structure, loose. Fairly sharp change to
B	26	Mottled very dark-brown and greyish-brown sandy organic hardpan, massive and coherent, with 6% grit. Sharp boundary to
C	33	Hard decomposing granite.

PROFILE H 72.

Beside Waratah Highway and Trig. station on Long Plains, 19 miles by road N.E. of Corinna (grid co-ordinates E 331000 N 890600). On moderate slope just below crest of a long ridge with open vegetation not more than two feet high, predominantly button-grass. Elevation 1400 feet, relief high, external drainage free but internal restricted by rock. Parent material quartzite and phyllite. Whole profile wet when sampled.

Horizon	Depth (inches)	Description
A_0	0	Very dark grey-brown peat, mainly humified but with coarse root mat. Massive and coherent. Indistinct change to
A_0	6	Very dark grey-brown well humified peat, massive and coherent, with 1% angular quartz grit. Indistinct change to
A_0-$_1$	12	As above with 4% grit. Sharp but irregular boundary to
C	17	Weathered quartzite and phyllite.

Analytical data for peaty surface samples from several parts of the area are given in Table II, and for profiles H 71 and H 72 in Table III. Analytical procedures are standard ones in use by C.S.I.R.O., Division of Soils, mainly as described by Piper (1942).

TABLE II.

Analytical Data for Surface Samples from Button-Grass Peats.

Sample	Depth inches	pH	Chloride NaCl %	Loss on ignition %	Organic carbon * C %	Nitrogen N %	C/N ratio *
T 626	0–3	4.2	0.03	23	10.0	0.41	24
T 631	0–6	4.1	0.05	72	30	0.99	30
T 635	0–6	4.3	0.03	34	14	0.65	22
T 638	0–3	4.4	0.01	33	14	0.42	33
T 639	0–6	4.4	0.01	27	11.5	0.45	26
T 640	0–6	4.3	0.04	33	14	0.55	26
H 71.1	0–6½	4.3	0.03	38	18	0.67	27
H 72.1	0–6	4.2	0.02	43	20	0.78	26

* Walkley-Black values.

All percentages are on the oven dry basis. pH is by glass electrode in 1 : 5 suspension.

These button-grass peats, as elsewhere in Tasmania, are strongly acid, though pH does tend to rise somewhat in the lower horizons. Hydrogen dominates the exchange complex, and levels of exchangeable calcium and magnesium are very low.

The small but measurable amounts of chloride present in these coastal soils are presumably due to cyclic salt. A higher figure of 0·15 per cent was obtained for a surface sample from the forested area of the plateau three miles from the coast, where the soil was fairly dry. Cyclic salt probably accounts too for the relatively high proportion of sodium, and perhaps also for the high proportion of magnesium, among the exchangeable metal cations.

Since the peats contain very little clay (Table III)) the figures for loss on ignition are a measure of organic matter. In common with other peats, the ratio of carbon to nitrogen is wide, averaging 27 for the eight surface samples when calculated from Walkley-Black values. (As W.B. values for organic carbon are lower than those determined by dry combustion, the C/N ratio as usually expressed would be around 35 for these peats.)

In the two typical profiles examined, "total" phosphorus (extracted by boiling HCl) is very low. This and the very small amounts of exchangeable calcium illustrate the infertility of these soils.

(*c*) *Other soils of the plateau.*—In the areas of open vegetation on the plateau there are some soils with much less organic surface horizons. In places this may be due to the burning out of a former peat cover, as the area has been subject to frequent fires both in the time of the aborigines and since, despite its heavy and well distributed rainfall. In other cases drainage may be sufficiently good so that peat does not accumulate. While most of the soils of the plateau are sandy, there are finer textured soils on the more argillaceous sediments in some places, notably about four miles east of the mouth of the Interview river.

In the timber belt two to three miles inland between the Pieman and Interview rivers, the soils have better drainage and one profile examined, a deep loose gritty sand, was almost dry to a depth of 30 inches. There is a fair surface accumulation of forest litter but the soils are generally less organic than those under button-grass.

A distinct profile having much of the character of a krasnozem, was examined under eucalypt forest on one of the long narrow low ridges which mark the basic dykes. This was a deep friable clay with crumb to fine angular blocky structure, brown to reddish-brown near the surface but yellow-brown below 20 inches.

(*d*) *Soils of the Sand Dunes.*—South of the Interview river the coastline is rocky and presumably steeply shelving so that no dunes form to landward of it, but the sandy beach from the Interview river northward has provided sand for dunes extending up to a mile inland. Here and further north beyond Sandy Cape there is evidence of two or more cycles of dune formation and stabilization. The drifting sands are rich in shell fragments, one sample containing 26 per cent by weight of carbonate (expressed as $CaCo_3$). Some dunes, mainly close to the shore, have been stabilized by native grasses and on these there is little profile differentiation. Two surface samples had respectively three and four per cent organic matter in the A_1 horizon, with much lower ratios of carbon to nitrogen than in the button-grass peats. Carbonate in various parts of two profiles ranged from five to 23 per cent (as $CaCo_3$) with pH above eight at the surface. In view of the strongly leaching climate, these data indicate that these dunes cannot long have been stabilized. By contrast, one dune

TABLE III.

Analytical Data for Two Button-Grass Peat Profiles.

Sample	Depth inches	pH	Chloride NaCl %	Loss on ignition %	Organic Carbon* C %	Nitrogen N %	Phosphorus P %	Exchangeable cations † m.e. %				
								Ca	Mg	K	Na	H
Profile H 71, near Interview River												
H 71.1 ..	0 – 6½	4.3	0.03	38	18	0.67	—	—	—	—	—	—
H 71.2 ..	6½–11	4.6	0.01	13.9	7.1	0.28	0.006	1.5	2.6	0.54	0.71	18.4
H 71.3 ..	11 –15	4.7	0.01	8.0	4.1	0.14	—	—	—	—	—	—
H 71.4 ..	15½–19	5.0	0.01	1.1	0.6	0.02	—	—	—		—	—
H 71.5 ..	19 –26	5.3	0.01	0.7	0.5	—	0.002	0.21	0.33	0.04	0.06	1.2
H 71.6 ..	26 –33	4.7	0.01	10.2	5.2	0.13	—	—	—	—	—	—
Profile H 72, Long Plains												
H 72.1 ..	0 – 6	4.2	0.02	43	20	0.78	—	—	—	—	—	—
H 72.2 ..	6 –12	4.2	0.01	21	9.6	0.34	0.004	1.1	2. 3	0.26	0.38	29.0
H 72.3 ..	12 –17	4.2	0.01	20	9.8	0.30	—	—	—	—	—	—

* Walkley-Black values.
† m.e. % = milliequivalents per 100 g. oven dry soil. Exchangeable hydrogen is to pH 7.0.

Particle-size Analysis of Mineral Matter‡.

Sample	Coarse sand		Fine sand		Silt plus clay
	2.0–0.84 mm. %	0.84–0.19 mm. %	0.19–0.072 mm. %	0.072–0.02 mm. %	less than 0.02 mm. %
H 72.2	6.1	36.6	34.8	12.1	10.3
H 71.2	21.6	50.3	22.9	5.2	
H 71.5	23.0	54.8	17.7	4.5	

‡ Expressed as % of total mineral fraction after removal of organic matter with hydrogen peroxide. Separation at 0.02 mm. by decantation, other separations by sieving.

All percentages are on the oven-dry basis. pH is by glass electrode in 1 : 5 suspension.

half a mile from the shore showed a typical groundwater podzol profile, indicating stabilization for a considerably greater period.

The height of one representative dune near the shore was measured as 175 feet. This and the finding of complete shells one inch in diameter on a drifting dune at about 100 feet elevation, testify to the strength of the dune-forming winds.

POTENTIAL LAND USE

Up to the present time the only agricultural use of the land north of Pieman Heads has been the winter grazing of cattle under the control of the Department of Lands and Surveys. The value of this grazing is doubtful. Even if its soils were more attractive, the isolation of the area would mitigate against agricultural development Only under extreme economic pressure would such development be worth consideration on the plateau with its shallow, poorly drained and strongly acid peaty soils, where very heavy initial dressings of lime would be required to raise pH sufficiently. The soils of the timber belt are probably better but the cost of clearing would be prohibitive. The stabilized sand dunes, and the drifting sands once stabilized, could support sown pastures if suitably fertilized, but would need careful management to avoid over-grazing and renewed movement of sand. Small areas on the terrace between the plateau and the coastline might be suitable for similar development if a future need for it should arise. With many more suitable areas available elsewhere in the State, there appears to be no such need at present.

ACKNOWLEDGEMENTS

Thanks are due to the Victorian Boy Scouts Association for organization of the camp and assistance with the traverses; and to other members of the Division of Soils, Mr. A. M. Graley and Mrs. E. M. Emms who carried out the laboratory analyses and Mr. A. Skoda who assisted with the field work. Unpublished climatic data were kindly made available by Mr. J. Walpole of the Hobart Meteorological Bureau.

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THE GEOLOGY OF THE ST. HELENS-SCAMANDER AREA, TASMANIA

By

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(*Communicated by Professor S. Warren Carey*)

(With 3 Maps)

ABSTRACT

The Scamander Slate and Quartzite consist essentially of a succession of stratified slates, quartzites and sub-greywackes with a few siltstone bands, which probably form part of the Mathinna Group. They contain primitive plants (*Hostimella* (?)) and are regarded to be of Siluro-Devonian age. They are intruded by a Devonian (?) quartz monzonite batholith, and possibly at a later date by St. Marys Porphyrite, which may however prove to be a dacitic flow. At present their structure is confusing; close parallel folding occurs which is overfolded from the west and complicated by numerous minor fault breaks. Major faulting in the area occurred in lower Tertiary, isolating the coastal plain physiographic unit from the hinterland.

The Permian System which follows unconformably has been divided into the following six formations:—

1. Sisters Granule Conglomerate.
2. Lohrey's Gully Sandstone and Calcareous Mudstone.
3. Enstone Park Limestone.
4. Binn's Gully Mudstone.
5. German Town Tillite.
6. Rays Hill Arkose.

The structure of these sediments is controlled by the Mt. Nicholas dolerite sill which intrudes them, and the concomitant faulting developed at the time of its emplacement in the Jurassic.

Lower Tertiary faulting and sedimentation during the Cainozoic resulted in the development of Tertiary wash covering the coastal plain to 350 feet above sea level, and probably the alluvial tin deposits at St. Helens were formed at this time.

Economic considerations reviewed include potential tin, tungsten, and copper deposits.

INTRODUCTION

The boundaries of the area mapped are defined by the co-ordinates 600,000 yards to 610,000 yards east and 800,000 yards to 910,000 yards north zone on the International Grid on sheet No. 4 of the 4-mile State map of Tasmania. The total area mapped is about 85 square miles.

The object of the survey was to produce a regional geological map of the area for submission to the University of Tasmania as a B.Sc. Honours Thesis. It was undertaken during 1952.

Aerial photographs were used to complete a base map from a slotted template layout controlled by trigonometric fixes, and for the plotting of field data. The aerial photographs were not amenable to photogeological interpretation, owing mainly to the regular development of topographic features by the systematic trellised drainage in the area, which gave rise to a monotonous repetition of hills and gullies of similar type. Photographs reveal only a few structural features such as some major faults. No characteristic photo patterns can be recognized from different rock and soil types or as a result of differential erosion.

Rock outcrop is poor, even though the soil cover is in general thin or absent. Disintegration of the short-jointed Scamander Slate and Quartzite has resulted in the shedding of a veneer of angular rock fragments, which conceals the underlying rocks. Consequently, boundaries between different rock types are indefinite, and this with frequent minor breaks results in confusion. The shattered nature of the terrain suggests a complexity of structure too detailed to be solved by this investigation.

Since the terrain is of poor quality, it is of little value for land settlement. Apart from the Tasman Highway, and the Golden Fleece Rivulet, the Upper Scamander and German Town roads, only a few access tracks exist to areas attractive to the timber miller.

Specimen and slide numbers referred to in this paper are of rocks kept in the Geology Department Museum at the University of Tasmania.

I am indebted to the Tasmanian Mines Department for the loan of microscope slides belonging to Twelvetrees (1911), and for access to unpublished reports.

I wish to express my appreciation to M. R. Banks, B.Sc., and A. Spry, M.Sc., for their help and numerous suggestions in the field and the laboratory, which aided in the compilation of this report. Finally, my thanks are due to Professor S. W. Carey and Dr. G. A. Joplin who critically read the manuscript and offered numerous helpful suggestions.

PHYSIOGRAPHY

Partially Rejuvenated Coastal Plain

In this unit rejuvenation has not resulted in so deep a dissection of the plain as it has in the hinterland. It extends the length of the area from Falmouth to St. Helens and further north, tapering from north to south; it is two to three miles wide at Diana Basin, and only one to two miles at Scamander. It dips gently east and seawards from its western margin, where it is elevated about 350 feet and abuts against the Coastal Range.

Subsequent rejuvenation has dissected the thin unconsolidated Tertiary sediments which cover the coastal plain so that youthful valleys of 100 feet to 150 feet depth have developed towards its western margin. Where denudation has been more extensive, the sediments have been completely removed, and the structure of the Scamander Slate and Quartzite and granitic rocks again controls the physiographic development, so that it then follows a similar pattern of development to that of the hinterland.

The coastal margin of the plain is lined with beaches, dunes and occasional rock outcrops. Dune development is more extensive towards the northern end where at St. Helens Point the dunes extend one-third of a mile inland. No elevated water-cut beaches occur.

The prevailing wind is northerly, which keeps the sand in constant movement, and is one factor preventing the migration of dunes inland.

Other coastal features developed along the plain are lagoons and barred basins, which include Hendersons, Wrinklers, Moriaty and Diana Basin These are filled by drainage from the hills to the west, and their outlets are barred like those of all creeks along the coast and that of the Scamander River. The water percolates below these sand bars into the sea, and during the wet season they dam back considerable quantities of water. Some low-lying zones are peaty with button grass, and sometimes marshy conditions prevail when drainage is poor.

To the south of Falmouth the St. Marys Porphyrite shelves flatly into the sea from the slopes of St. Patricks Head. In this area the coastline is essentially one of porphyrite outcrop with occasional small inlets and beaches.

Strongly Rejuvenated Hinterland

Topography

The second unit, the hinterland, forms a low mountainous region. This physiographic type extends west from the Coastal Range beyond the western boundary of the area. It is interrupted by granitic terrain to the north of the Golden Fleece Rivulet, and continues as far south as the northern slopes of the Mt. Nicholas Range.

Its youthful topography has been moulded by a trellised drainage pattern forming typical V-shaped valleys. On the whole the hills and ridges are slightly higher in the west. The Coastal Range averages 800 feet to 1000 feet, and the Scamander Tier reaches nearly 1500 feet in places. This suggests that if a pre-lower Tertiary plain existed, it dipped gently eastwards.

The Coastal Range runs roughly parallel to the coast, having an axial trend a little west of north. Scamander Tier converges to within a mile of the Coastal Range at its northern limit adjacent to Flagstaff Hill, and is terminated in the south by the Scamander River, 2½ miles west of the Coastal Range. This general north-south trend of the ranges and country may indicate that lines of weakness developed parallel to the coast.

All the hills are of the narrow straight ridge type and are invariably steeper on the south-west side with gentler slopes on the north-east flank.

The higher and more rugged peaks are dolerite of St. Patricks Head to the south, and the Mt. Nicholas Range, and the North and South Sister in the south-west corner of the area. They expose the usual columnar and precipitous outcrops so characteristic of Tasmanian physiography. In this south-west corner of the area, physiographic development has been controlled by columnar dolerite and modified by the Permian sediments. At German Town solution of Permian limestone undermined the terrain, causing subsidence in a number of places.

Drainage

The development of the trellised drainage pattern has been influenced by structural features of the rocks, such as prominent jointing and faulting, rather than by differential erosion of the various rock types of the area. This is especially so with the Scamander Slate and Quartzite intruded by granitic rocks.

A series of roughly parallel faults has controlled the development of many of the gullies in the St. Marys Porphyrite. This is demonstrated in the contact zone between the porphyrite and the Scamander Slate and Quartzite.

The major streams draining the area are the Scamander River and the Golden Fleece Rivulet, and a small portion of the area to the north of St. Helens is drained by tributaries of the George River. Apart from these, numerous coastal creeks drain eastward into the sea, while those west of the Coastal Range usually flow north or south and empty their contents into the Scamander River. The most important of these is Eastern Creek, which drains the valley between the Coastal Range and Scamander Tier.

Similarly, to the south of the Scamander River, the ridges and creeks run parallel to the coast from the hills around German Town, and the creeks drain northwards into the Scamander River. The eastern slopes from German Town, and the north-eastern slopes from St. Patricks Head, are drained by creeks flowing seaward, which invariably are controlled by faults.

Constable and Ferntree Creeks drain the northern slopes of the Scamander Tier and flow north-east into the Golden Fleece Rivulet.

George River is the longest river in the extreme north of the area draining the relatively low granitic country, and has its outlet in George Bay. The greater part of its water is derived from north of the area under review.

The Scamander River is the major river in the area. It rises in high ground some miles west of Hogan's Track, and flows south-east until it unites with the Avenue River about 8 miles from the sea. From here it pursues a more or less easterly meandering course, and at the coast it is estuarine. In this part of its course it crosses the general trend of the strata, and flows nearly at right angles to the direction of the mountain ranges. The present mouth has been developed along a prominent fault line in the Scamander Slate and Quartzite, whose steep rocky banks plunge below the water line without the formation of shingle or sandy beaches. The sand bar at its mouth is only open a few times during the year and it then becomes tidal for about 4 miles upstream.

It is considered that its present mouth is not the original outlet to the sea. Prior to Tertiary deposition it flowed along the first mile of the Upper Scamander road and then along the length of Henderson's Lagoon, probably finding an outlet to the sea at Falmouth. Either Tertiary sediments have filled the old Scamander River bed and forced it to exploit the fault line along which it now flows to the sea, or, more probably, this course was initiated by some form of river capture. Evidence of its old course is recorded by gravels 10-20 feet above sea level.

The sealing off of the outlet of the Scamander River has caused its adjacent lower reaches to become extensively silted up and consequently to develop ox-bow lakes and broad silt flats which are quite fertile.

Physiographic Development

The completeness of the cycle of erosion before the land surface was inundated by Permian seas cannot be determined exactly from the fragmentary evidence available. Permian sediments are found to cap a number of the hinterland topographic highs and their altitude is approximately the same.

The Permian on the coastal plain near Falmouth (884,250-603,550) is about 1300 feet below its equivalent horizon at German Town, and occurs too far west to be downthrown by a single fault along the eastern base of the Coastal Range, which separates the two physiographic units. This infers that the separation of the coastal plain from the hinterland is not due to a single fault. Field and aerial photograph evidence indicates a complex series of step faults in the St. Marys Porphyrite contact-zone causing the relative displacement of the Permian.

The Mesozoic land surface was possibly peneplained before the deposition of a veneer of Tertiary wash on it, and before lower Tertiary faulting occurred. This is shown by the fact that the Tertiary wash is fairly even in thickness through a large range in present attitude, to 350 feet above sea level on the coastal plain. Gentle east dip of this pre-Tertiary erosion surface is also shown by the hills being slightly higher in a westerly direction.

There is no doubt that lower Tertiary faulting has exerted a marked control on the physiographic development in the area, resulting in the general north-south trend of physiographic features. It elevated and tilted the coastal plain separating it from the hinterland, which represents a more strongly rejuvenated portion of the Mesozoic land surface, and hence shows more deeply cut valleys.

SILURO-DEVONIAN SYSTEMS

Scamander Slate and Quartzite

For the purposes of this paper the oldest succession of sediments in the area will be referred to as the Scamander Slate and Quartzite, pending further information regarding their correlation with rocks in other parts of the State. It may be a formation, but not enough is known to define it as such. The highest and lowest members are not known, but possibly a fairly complete sequence is exposed in the Upper Scamander road cutting and along the coastal outcrop one mile north of Diana Basin.

Although the Scamander Slate and Quartzite is at present considered as a separate unit, it will probably later prove to be the same as, or part of, the Mathinna Group (Hills and Carey 1949). There is a marked similarity between the two, and similar rocks appear to continue in an unbroken line to Mathinna and north through Mt. Victoria to Warrentinna and Gladstone. Little aid to correlation is available from fossil remains.

The Break of Day Rivulet between Mt. Nicholas and St. Marys Pass marks the southern limit of the Scamander succession and in this parallel the sediments pass beneath the dolerite of the Tiers. The succession extends north from the St. Marys Porphyrite contact, forming the main portion of the hinterland, until it is cut off by granitic rocks in the St. Helens area, along the line of the Golden Fleece Rivulet.

Exposures of the Scamander Slate and Quartzite are not good, and as mentioned the best sections occur in the Upper Scamander road cuttings, and along a coastal outcrop one mile north of Diana Basin. Apart from these, exposures are confined to the occasional precipitous valley wall. The paucity of outcrop results from the disintegration of indurated bands of stratified sediment, which are short-jointed and cause an extensive veneer of angular rock fragments to cover slopes in place of soil and rock outcrop. Accumulations concentrate on valley floors after migrating down grade. Talus is usually quartzite, though accumulations of slates also occur in places and these in some instances reflect the nature of the hidden rock type.

In general, the Scamander Slate and Quartzite, where exposed, form a remarkably simple succession of sediments. They are either massive and structureless in outcrop or have monotonously constant structural features. They comprise a succession of closely stratified slate, siltstone, quartzite and sub-greywacke.

Intraformational Structures

Minor intraformational structures include depositional rolls and corrugations, which occur between slate and quartzite horizons. They develop in both slates and quartzites along planes representing

changes in lithology. The direction of the rolls is usually parallel to the strike, but in a few cases it is seen parallel to the dip.

Occasional slump structures are seen, especially in the sandstone. An example of this structure occurs in a band of sandstone in an Upper Scamander road cutting near the big bend of the Scamander River, and it suggests a movement forward and westward.

Current bedding only occurs in a few narrow bands of quartzite, and indicates currents from the east in places where the beds are not overturned.

A distinctive breccia occurs close to the St. Marys Porphyrite contact, and along the greater part of its length. It has not been seen elsewhere in the area, though it appears to bear no apparent structural relationship to the Scamander succession or the porphyrite. Although it is well developed, its occurrence is unpredictable and in some places it is limited or absent. It may appear as isolated pockets of recemented angular debris, filling joints and other apparent cavities in the Scamander Slate and Quartzite. It contains angular fragments of quartzites, but no fragments of porphyrite. Its fabric and metamorphic character (see below) discount the possibility of an overthrust of the porphyrite on to the Scamander Slate and Quartzite. If it is a fault breccia its sedimentary character, metamorphic grade, and exclusive association to the St. Marys Porphyrite contact zone remain an enigma. The only other possibility is that it is a breccia of recent origin.

Fossils

Fossils are rare. Plant remains include the primitive plant *Hostimella* (?) described by Cookson (1936). She considers that it can be assigned to an upper Silurian age. The pieces preserved are fragmentary, and the best specimens are found in the fine to medium grained carbonaceous sub-greywackes and slates.

Other dwarf fossils occur in lenses of porous intra-formational conglomerate. They are exceptionally rare and include bryozoans, corals, brachiopods, and crinoid columnals as moulds. The fossils indicate a place of burial and not growth.

Provisionally the age of the Scamander Slate and Quartzite may be considered to range between middle Silurian and middle Devonian, but are possibly lower Devonian.

Depositional Environment

It is impossible to give any estimate of thickness of the succession. The sediments were probably deposited in a marine basin in the upper Silurian or lower Devonian. The source of the material was possibly a low mountain range to the east of the area. The intraformational structures indicate currents from the east. The depositional environment would not be congenial for the development of a large unbroken thickness of sediments unless sedimentation took place in a slowly sinking basin. Alternately the oscillatory shore line gave rise to deposition of thinly interbedded stratified shales, siltstones, sandstones and sub-greywackes. Minor depositional structures indicate that the floor of deposition was sloping to the west.

Petrography

Most specimens come from the Upper Scamander road cuttings, though some have been collected from other parts of the area.

Petrological examination of specimens reveals a close similarity in composition between rock types. All except the quartzite differ mainly in texture and granularity, ranging from sub-greywacke siltstones to fine and medium grain sub-greywacke.

The quartzites are sometimes irregularly fractured (4763, 4727 and 4725), which probably results from the different physical reaction of their texture to stress as compared with the sub-greywacke siltstone textures.

No pyroclasts or other volcanic rocks are seen in the succession

All these sediments show changes due to low grade thermal metamorphism, which was not sufficient to destroy their original texture. Except for localized contact zones, the change was uniform.

Petrologically, the sediments can be classified into three groups according to table 1.

The Contact Between the Scamander Slate and Quartzite and the St. Marys Porphyrite

The metamorphic character of the Scamander succession adjacent to the St. Marys Porphyrite contact is significant when considering the origin of the porphyrite.

Specimens of fine-grained sub-greywackes (4759, 4653 and 4656) cannot be collected *in situ* within 10 feet of the porphyrite contact. In general, sedimentary outcrops are structureless, but at 885,950-601,975 bedding strikes 227° and dips 88 SW. The specimens show little more than low-grade thermal metamorphism consistent with those listed in Table 1. Slight baking of the immediate contact sediments may have occurred, but this contact surface is concealed under rubble.

A large fragment of country rock (4651) caught up within the porphyrite contact zone shows stronger thermal alteration. Porphyroblasts of quartz and felspar occur in its fine micaceous matrix. The granoblastic fabric of the groundmass consists of interlocking quartz grains, some of which are cracked and show wavy extinctions. A few large round waterworn (?) grains of quartz remain and measure up to 1·2 mm. in diameter. Plagioclase grains measure up to 2 mm. in size, many are cracked and altered to sericite. The groundmass contains small grains of felspar, quartz, green biotite and flecks of chlorite. The original sediment was possibly more argillaceous than 4759, 4653 and 4656 (which occur 10 feet from the porphyrite contact) but it may be partly felspathised.

Sections of the breccia referred to on this page show it consists of recemented angular fragments of Scamander quartzite. The matrix in 4661 and 4662 is similar to that of the sub-greywacke siltstone listed in Table 1, except some slides cut by siliceous veins. Resolution of grains in the matrix is poor. The matrix consists of minute quartz grains, fine micaceous needles and flecks of carbonaceous material. Once again, the alteration is low thermal.

TABLE 1

Field Name.	1. SUB-GREYWACKES. Slates and Sub-greywackes.	2. SUB-GREYWACKE SILTSTONES. Claystones and Siltstones.	3. SANDSTONES AND QUARTZITES. Sandstones and Quartzites.
GRADE	Arenite. Fine grained—0·06 mm. to 0·25 mm. Medium grained—0·25 mm. to 0·6 mm.	Lutite. Even grained 0·01-0·04 mm.	Arenite. —
FABRIC	Sedimentary.	Sedimentary—occasional siliceous veins—some banded with orientated mica laths (4753, 4754). Others spotted—perhaps as a result of incipient centres of crystallization or mica development (4705).	Sedimentary—some quartzites are intergranular (4763, 4731). Grains often show parallel (4763) and irregular (4727) fracturing.
SORTING	Poor.	Good.	Poor.
ROUNDING	Angular to sub-angular.	Angular to sub-angular.	Sub-angular to sub-rounded.
MINERALS AND HEAVY MINERALS	Quartz 60-80% shows part or complete reconstitution of grains and some of which are larger than the matrix granularity. Biotite and muscovite—small and large grains. Chlorite and sericite—small amounts as needles and laths. Felspar, iron ore, sphene tourmaline and apatite grains are rare.	Resolution of some grains impossible. Quartz—grain size 0·02-0·04 mm.—show partially reconstituted grain margins. Few large grains to 0·1 mm. size. Chlorite, muscovite splinters and little biotite (4754). Apatite and zircon grains are rare (4758).	Quartz-grain size 0·2-0·6 mm. Tourmaline—large rounded grains (4763, 4731). Biotite (4728). Muscovite—few grains (4727, 4731 and 4730). Occasional zircon grains and pyrite cubes.
ROCK FRAGMENTS	Mainly quartzite 1-10%.	—	Quartzite in 4763, 4727 and 4728.
MATRIX	Micaceous from original argillaceous material 10-30%.	Micaceous 30%. Carbonaceous in some cases 10-20%.	Little interstitial mica to interlocking quartz grains 0-5%.
CEMENT	Some rocks ferruginous 1-5%.	—	Up to 10% ferruginous in 4727.
COLOUR	Buff, red-brown, blue-grey and black micaceous and carbonaceous varieties.	Green, purple and brown. Light to dark-grey banded.	Buff tending to darker colour with depth.
BEDDING	Laminated, fissile and some typically slaty.	Poorly cleaved, laminated in places.	Sandstones and argillaceous sandstone—massive and structureless. Indurated quartzites—strongly short jointed. Stratified beds with slates and sub-greywackes.
OTHER FEATURES	Gas bubbles in some quartz grains. *Hostimella* (?) occurs in carbonaceous sub-greywackes.	Siliceous and micaceous banded grey varieties occur, some with clay pellets.	Some quartz grains contain numerous inclusions.
METAMORPHISM	Very low thermal.	Very low thermal.	Low thermal in places slight crushing of quartz grains.
ORIGIN OF MINERAL GRAINS AND ROCK FRAGMENTS	Derived from metamorphic and igneous rocks.	—	Derived from metamorphic and igneous sources.

TABLE 2

	Rays Hill Arkose	German Town Tillite.	Binn's Gully Mudstone.	Enstone Park Limestone (Calcilutite to Calcarenite).	Lohrey's Gully Sandstone and Calc. Mudstone.	Sisters Granule Conglomerate.
THICKNESS (FT.)	70	20	120	60	55	15
GRADE	Arenite medium to fine grained.	Lutite medium grained.	Lutite coarse grained.	Lutite (arenite). Coarse to fine grained.	Arenite, medium-grained lutite, coarse grained.	Rudite fine grained.
SORTING	Fair.	Poor.	Good.	Good.	Fair to good.	Good.
ROUNDING	Angular to sub-angular.	—	Sub-angular to sub-rounded.	Angular to sub-rounded.	Angular to sub-angular.	Sub-angular to sub-rounded.
MINERALS	Quartz, muscovite and 40% felspar.	Quartz, felspar, calcite.	Quartz and felspar.	Calcite.	Quartz, felspar and chlorite—glauconite (Brill. 1955).	Quartz and felspar.
ROCK FRAGMENTS	Quartz, quartzite sub-angular to sub-rounded.	Common water-worn, angular, mostly faceted.	Rare.	Common mostly small angular, many rock types.	Common quartz (colourless grains) schists, &c.	Uncommon.
CEMENT	Ferruginous.	—	Calcareous.	—	—	Argillaceous (Kaolin) and Ferruginous.
COLOUR	Grey.	Grey.	Grey to buff.	Grey to cream.	Yellow to green.	White to buff.
BEDDING	Massive.	Flaggy to massive.	Shaly to massive.	Flaggy to massive.	Shaly to massive.	Massive.
OTHER FEATURES	Contains erratic pebbles and exposes bow fronted and domed outcrops.	—	Clay pellets and stray pebbles.	Relatively pure, stray pebbles and cliff faces rich in fossils.	Becomes coarser grained upwards. Numerous colourless quartz grains.	Colourless to milky quartz.
FOSSILS	Contain a few marine and plant fossils.	Contain a few marine and plant fossils.	Some marine fossils.	Corals, Bryozoa, *Martiniopsis*, spiriferids, productids, *Lyroporella*, aviculopectinids. *Streblotrypa*, *Eurydesma cordatum* var. *sacculum*.	Unidentifiable fossils.	Unfossiliferous.

Considering the overall thermal metamorphism recorded in the Scamander succession, contact effects are almost negligible in the contact zone as a result of emplacement of the St. Marys Porphyrite. This feature of the porphyrite suggests a flow origin for this igneous mass.

PERMIAN SYSTEM

Distribution of Sediments

The Permian sediments occur in the south-western corner of the area, and lie unconformably on the St. Marys Porphyrite and Scamander Slate and Quartzite. Evidence is fragmentary, since the restricted sequence of sediments occurring in the area has been disrupted by the injection of dolerite dykes and sills forming the Mt. Nicholas Range. They form part of a suite ranging from ortho-quartzite to limestone. One exposure represents an unbroken sequence occurring at 880,650-600,750 to 880,750-600,550 on the southern flank of Rays Hill. The Permian also occurs further east of this, in the Enstone Park Estate at Falmouth (884,250-603,660) where it is relatively lower by 1300 feet than the equivalent beds at German Town, as a result of the lower Tertiary faulting.

Sub-Division into Formations

The section at 880,650-600,750 to 880,750-600,550 exposes six formations. The remainder of the Permian outcrops are isolated blocks in the dolerite intrusive which constitutes Rays Hill. Sub-division into formations from the fragmentary evidence available shows the succession to be (see table 2).

"Dolerite Sill".
Sisters Granule Conglomerate.
Lohrey's Gully Sandstones and Calcareous Mudstone.
Enstone Park Limestone.
Binn's Gully Mudstone.
German Town Tillite.
Rays Hill Arkose.
Basement—Scamander Slate and Quartzite and St. Marys Porphyrite.

TERTIARY SYSTEM

Distribution of Sediments

The unconsolidated Tertiary wash on the coastal plain, and the partly consolidated Tertiary sediments of George Bay, lie unconformably on Permian sediments, granitic rocks and the Scamander Slate and Quartzite. The cover at Diana Basin is three miles wide, compared with one and a half miles in the vicinity of Scamander, tapering from north to south, and finally petering out near Falmouth.

As mentioned, an east-west section of Tertiary on the coastal plain shows that the thin cover persists as a veneer on a gentle east dipping grade from the base of the Coastal Range to sea level. At the foot of the Coastal Range, Tertiary sediments remain only on crests of hills and spurs, and on the coast the basement rocks are frequently uncovered.

The cover in the Falmouth area is not nearly as thick as it is at St. Helens, where extensive sediments 150 feet thick accumulated, concealing the basement rocks completely. In the George Bay area the beds are relatively thick and consolidated, possibly because a barred basin may have existed there during deposition.

Lead development in the St. Helens area probably belongs to this same epoch.

The wash on the coastal plain consists of a veneer of unconsolidated waterworn pebbles of quartz and quartzite scattered in a loamy soil, with numerous isolated occurrences of bedded ferruginous quartz granule conglomerate. In many places is found lining the base of the Coastal Range delineating the coastal plain physiographic unit from the hinterland. This represents the highest occurrence and is about 350 feet above sea level. In many places it is found on crests of hills where it is bedded (903,330-610,850), or current bedded (905,180-606,040 and 904,860-605,600) and which also contains numerous poorly-sorted, angular or waterworn quartz pebbles, as well as fragments of slates and quartzites from the Scamander succession, in a ferruginous cement. Poor sorting and rounding of quartz grains indicate a fairly local source for this material.

South of the Golden Fleece Rivulet (905,110-602,100) a large U-shaped area of wash occurs which may be Tertiary. Here, the ferruginous granule conglomerate is found some 250 feet above sea level, again on the summit of hills. The axis of this sedimentation runs roughly parallel to, but a little east of Constable Creek. It extends southward and just west of the northern end of the Coastal Range, and differs from the coastal plain wash in the almost complete absence of the white waterworn quartz pebbles, and the less extensive development of loamy soil cover.

The cover in this area consists of sub-angular to sub-rounded, poorly sorted fragments of Scamander quartzites. Consequently, the ferruginous granule conglomerate contains sub-angular fragments of Scamander Slate and Quartzite in place of the rounded quartz pebbles seen on the coastal plain. This probably reflects different source material from that of the coastal sediment.

Age and Origin

The most important considerations in the determination of the origin and age of the wash are its distribution (it is confined to the coastal plain), and the regularity with which it appears to lap up to the 350 foot contour on the eastern flank of the Coastal Range. The height of its occurrence above sea level and consistency of distribution eliminate the possibility that it resulted from eustatic fluctuations of sea level, especially those relating to the Pleistocene glaciation. It is unlikely, but not impossible, that it represents remnants of an old ferrugineous crust, whose formation was contemporaneous with lateritic crusts developed in other parts of the State, and that it has been removed from the hinterland by subsequent erosion.

No evidence exists to indicate that these sediments have been faulted, and it appears that conditions of sedimentation reflect their formation during or after lower Tertiary faulting. The exact origin and process of development of the wash remains unknown, but if it were developed during that time, it is either a flood plain deposit or marine wash elevated and isolated from the hinterland by faulting.

The absence of marine fossils and foraminifera, the poor sorting of the unconsolidated sediments, and the sub-angular to sub-rounded character of the rock fragments, all suggest fluvial or flood plain origin from local source material rather than marine deposition. Also, no elevated coastal physiographic features are apparent or preserved in the coastal plain area.

Alluvial Sediments

Alluvial tin-bearing localities differ in a number of places. At 906,050-602,060, an old tin sluicing area, sluicing exposes poorly sorted slate and quartzite fragments in a matrix of yellow ferruginous clay deposited on Scamander Slate. This material is angular to sub-rounded, and possibly not transported far from its source.

Deposits along the Upper Scamander road have been worked for alluvial tin and these probably occupy the old course of the Scamander River when its outlet was in the Falmouth area.

In the St. Helens area the thickness of the lead deposits changes, increasing towards their mouth. Nye (1933) estimates that Thureau's Lead is 200 feet thick in the north-south portion of the Golden Fleece Rivulet. The bottom of the lead is below sea level where it crosses Medeas Cove and is some 200 feet above sea level near Goshen. These ferruginous and argillaceous quartz granule conglomerates, and are characterized by lead deposits in their superficial layers (Nye, 1933). He also states that it appears that the upper beds or higher horizons of Thureau's Lead were tin-bearing to a much greater extent than the lower ones, and that this infers that the land surface remained at much the same level for some time during concentration in the upper beds, or the greater part of the primary tin was not uncovered until the formation of the upper beds of the lead, or finally, the upper levels of the original leads have been denuded and as a result the tin has been concentrated in 5 to 10 feet of derived gravels.

At present no accurate information exists to date the leads. Provisionally they may be considered Tertiary and equivalent to those which are covered by Tertiary basalt flows in the Derby area, though they need not necessarily be related to those deep leads. The fact that nowhere are the leads reported to be dislocated suggests that they are not earlier than the lower Tertiary faulting.

Whether any relationship exists between the leads and eustatic fluctuations of sea level in the Pleistocene seems doubtful, though some reworking of deposits may have occurred. If any Pleistocene sediments exist in the area, unravelling them from Tertiary deposition on the scale of mapping undertaken would be impossible. Hence, in localities such as George Bay disentangling of Cainozoic sediments is not easy because of the uniformity of source material.

The rapid erosion and modification of the land surface following lower Tertiary faulting has been suggested by S. W. Carey (personal comment) as the logical time when lead development could take place, and ensuing sedimentation could comply with the controlling factors of tin source and deposition.

RECENT

Alluvium covers the area in a number of places, especially river flats and flood plains. Such alluvial flats occur at Binn's Gully near Falmouth, the lower reaches of the Scamander River, and also an extensive development surrounds St. Helens.

IGNEOUS GEOLOGY

The Coastal Range Quartz Monzonite

Field Observations

The main exposure of quartz monzonite in the area roughly corresponds to the axis of the Coastal Range, crossing it diagonally from its eastern side in the south to its western side in the north. At the Constable Creek tungsten mine, the granitic outcrop possibly represents the apex of a cupola. Granitic rocks also extend from the Golden Fleece Rivulet beyond the northern boundary of the area under review. This extension constitutes the southern portion of a large granitic mass which passes north-west to Derby and as far north as Gladstone. Numerous other exposures occur, especially along the coastal plain. Twelvetrees (1911) reports that Paddys Island and St. Helens Island appear to consist of light-yellow muscovite granite, similar to an occurrence which crops out on the coast at St. Helens Point.

The area of granite mapped is 7 square miles. It intrudes the Scamander Slate and Quartzite with sharp transgressive contacts.

The coastal section, 1 mile north of Diana Basin from 903,490-610,850 to 903,650-611,050, reveals that the magma intruded by plucking slabs of country rock from the roof and wall of the magma chamber, possibly by piecemeal stoping (Daly, 1933), and assimilating these xenoliths in its upward migration. Xenoliths in all stages of assimilation were suspended in the magma when it consolidated, and gave rise to localized zones of contamination within the granitic rocks, now recognized by zones enriched in ferromagnesian constituents. Such zones occur in both central and marginal portions, but are more common towards the margins. Different localized modifications of texture and mineral content in the field, at first appearance, give the impression that the batholith is a heterogeneous acid igneous mass, since such zones have no definite boundaries between them.

At 910,910-605,620 and 911,140-605,820, orientation of ferromagnesian minerals is a localized effect. This would result from flow in the magma (Balk, 1937), or from injection of the magma under lateral pressure, giving it a gneissic structure as seen at 911,010-605,020, where foliation is 330°.

Both quartz monzonite porphyry and porphyritic quartz monzonite may be found. At 910,300-608,400 to 910,600-608,300 phenocrysts in the porphyritic monzonite are orientated 190° and average 4 cm. long, with some as large as 7 cms.

Different phases of granitic activity have been recognized. At St. Helens Point the biotite granitic type has porphyritic phases as elsewhere, and also contains xenoliths. Boulders of basic rocks, similar to those seen intruding the quartz monzonite north of Diana Basin, occur in this region too. Pegmatite phases associated with the muscovite granitic type intrude the biotite granitic type of the area, and it is evident that this leucocratic phase is the younger.

Numerous apophyses are associated with the Coastal Range quartz monzonite in its marginal zone. These are aplitic, pegmatitic and dioritic dykes and sills. The few aplitic dykes do not extend more than a chain from the contact, as demonstrated by that at 903,500-611,000 which strikes 125° and tapers from one foot to an inch in 75 feet. The diorite porphyry dykes and sills are referred to below as they are a late phase of the quartz monzonite intrusive.

The temperature of intrusion of the quartz monzonite was sufficient to plastically deform the immediately adjacent country rocks, yet induced only low-grade thermal metamorphic changes and minor contact effects in them.

A rough estimate of thickness of the overlying country rocks, at the time of intrusion, is a minimum of 5000 feet. This is a doubtful estimation derived by projecting the base of the St. Marys Porphyrite north and calculating its height above the batholith. Thus, the assumptions are made that little erosion occurred between intrusion of the granitic rocks and emplacement of the St. Marys Porphyrite and that the St. Marys Porphyrite has not been subsequently tilted.

Many granitic exposures show typical spalling, mural jointing and domed surfaces. Weathering is extensive in some localities, especially north of the Golden Fleece Rivulet. Great thicknesses of decayed granitic rock, which show original structural features, are exposed in some road quarries. It is for this reason that finely disseminated tin can be hydraulically mined *in situ* from the decayed granite.

Petrography

The Coastal Range quartz monzonite is a light-grey, medium to coarse grained rock showing facets of felspar and quartz, with a plentiful sprinkling of biotite flakes.

In section the rocks are typically granitic, except for 4673 and 4666 which have an almost granoblastic character, and are finer than average grain size. There are a number of different textural modifications but these are localized features. Finer aplitic textures are rare, but coarser porphyritic ones are common. The fabric of the porphyries (4736, 4723 and 4715) shows felspar and corroded quartz phenocrysts. Other localized textural modifications include graphic intergrowth in 4692 and 4690, and the perthitic texture in 4675 and 4701. Poikilitic and myrmekitic textures occur in 4678, where phenocrysts of microline contain small inclusions of plagioclase and quartz grains.

The general texture of the quartz monzonite is not typically monzonitic, but approximately equal proportions of potash and plagioclase felspars and abundant quartz give the granitic rock a quartz monzonite composition.

Directional trend of ferromagnesian minerals corresponds to foliation in 4666 and 4668. Other stress features are localized minor effects such as slight shearing and the development of chlorite in 4668 and the crushing or localized mylonitization in granitic rock 4691.

Potash felspar and plagioclase in slides of granitic fabric can be as large as 3 mm. Phenocrysts are larger than this in the porphyries 4703 and 4666 and in the porphyritic quartz monzonite they are usually of potash felspar rather than plagioclase. Zoning in plagioclase is more characteristic of the phenocrysts than it is of ordinary grains, and adjacent zones differ only slightly in composition, alternating rather than becoming progressively more acid. Plagioclase shows slight to extensive alteration, and this is especially noticeable in the zoned crystals which are normally completely altered. In some a particular zone may be altered (4766, 4697 and 4715), and in 4766 the core of a perfectly zoned crystal has been completely altered to sericite, while the outer marginal zone is fresh plagioclase. This selective zone alteration indicates changes in the magma during plagioclase crystal development. Evidence in 4708 of twin lamellae being ruptured, probably reflects movement in the magma during crystallization. Plagioclase composition determined by extinction angle measurement of twins according to the albite law, or combined Carlsbad-albite laws, indicates a remarkably consistent composition within the range $Ab_{65}An_{35}$ and $Ab_{55}An_{45}$, and therefore is always andesine. The average composition for all slides examined was $Ab_{58}An_{42}$. The average relative abundance of plagioclase by visual estimation from 40 sections is 30 per cent.

The consistent composition of plagioclase in all specimens of granitic rock types examined probably indicates their close affinities to one another. Apart from the extremely basic phases, andesine is the composition of the plagioclase whether determined from pure quartz monzonite or from zones of the original magma showing differing degrees of contamination.

In the porphyritic quartz monzonite variety, potash felspar invariably occurs as phenocrysts, although this is not the case with the quartz monzonite porphyry. In the even-grained granitic textured rocks it forms interlocking grains with quartz, and like plagioclase, is rarely fresh. Microcline is the usual potash felspar present, although a few grains of orthoclase have been recognized. Potash felspar was often recognized by using staining tests (Chayes, 1952). Grains average 2 mm. in size in the quartz monzonite and in the porphyritic quartz monzonite phenocrysts reach a maximum size of 1 cm. As mentioned, in field exposures of the same rock, phenocrysts,

as large as 7 cm. have been recorded (910,800-608,400 to 910,600-608,300). The average relative abundance is 30 per cent determined by visual estimation from 40 slides. As in the plagioclase, the porphyritic texture of some slides made estimations unreliable.

Quartz occurs as anhedral grains interlocked with felspar and ferromagnesians in slides with granitic fabric, and as euhedral phenocrysts with corrosion embayments in the marginal porphyries (4768, 4715, 4736 and 4723). Grains up to 1 cm. occur in the porphyry but in the porphyritic quartz monzonite they average 5 mm. as part of the granitic groundmass and never form phenocrysts. Many grains are fractured with irregular cracks (4675). In the 40 sections examined quartz averages 40 per cent.

Biotite is the dominant ferromagnesian mineral in the uncontaminated quartz monzonite and in many sections it is the only dark mineral present. In the porphyritic quartz monzonite it occurs in the groundmass and in the porphyry it forms phenocrysts (4700). These are usually anhedral flakes, though sometimes laths are present. Biotite grains interlock with other mineral grains of the quartz monzonite as a minor primary constituent. In some instances, flakes are bent (4715) and in 4666 and 4668 distinct orientation of the biotite flakes reflect foliation seen in the field. It is nearly always the pleochroic light to dark-brown variety with a 2 V about 14° (4703). In the quartz monzonite it consistently constitutes 5 per cent of the rock.

Alteration of biotite to chlorite along cleavage planes results in bands of biotite alternating with chlorite (4678, 4675 and 4766). Other grains show alteration veins of chlorite (4715), while others still are completely altered to chlorite (4736 and 4768). Biotite in 4684 has developed along the cleavage traces of felspar which indicates its later development.

Very few accessory minerals are present in the Coastal Range quartz monzonite. They include a few small grains of sphene, apatite and magnetite. Pyroxene is never seen in the uncontaminated granitic rock.

Secondary Alteration and Pneumatylosis

Deuteric alteration affected most minerals at some time or another during the later stages of crystallization. In part, this may be responsible for minor modifications in composition of the granitic rocks. The effects have already been described with respect to selective saussuritization of felspar grains and alteration of biotite flakes to chlorite.

Amphibole in zones of contamination is altered to epidote while in other cases it is altered to calcite and chlorite as in 4708, 4693, 4691, 4694 and 4695, and in 4736 hornblende and pyroxene are pseudomorphed by calcite and chlorite. In a few slides (4674, 4675, 4684 and 4715) hornblende is an accessory mineral of the quartz monzonite, possibly resulting from localized deuteric alteration. Epidotization has occurred in some other slides (4664). Muscovite is widespeard, especially in the Constable Creek mine area (4765, 4701 and 4702) and other zones of mineralization (4734, 4672 and 4764). This probably results from gneissenization the more leucocratic granitic type at St. Helens Point. Such zones are particularly susceptible to weathering and have been deeply decayed as a result.

Crystallization of the Magma

The history of plagioclase development and zoning, dislocation of twin lamellae, bending of biotite flakes, and irregular cracking of quartz grains suggests that a liquid magma was injected and movement probably occurred during its consolidation. Corrosion embayments in the quartz phenocrysts definitely indicate a fluid origin for the marginal quartz monzonite porphyry. Halts in crystallization and changing composition of the magma during consolidation are also indicated by the selective zoning and alteration of felspar and biotite minerals.

The petrological investigation in association with field evidence provisionally indicates that the granitic mass and its variations belong to one igneous cycle of intrusion.

More Basic Phases

As mentioned, the amount of biotite in the quartz monzonite is consistently 5 per cent. Only slides 4678, 4715, 4766 and 4736 show a higher relative abundance than this, and approach 10 per cent. In these slides biotite is usually intimately associated with approximately equal proportions of hornblende. In some slides hornblende is the dominant ferromagnesian mineral, to the exclusion of biotite and quartz, and in extreme cases may represent as much as 25 to 40 per cent, and therefore approach a dioritic composition. It is thought that this later dioritic type gave rise to the development of the diorite porphyry apophyses, possibly as a result of some filter-press action operating on a zone of extreme contamination, and which is a localized zone in the quartz monzonite magma resulting probably from the assimilation of some sedimentary rock types.

The normal green amphibole is the predominant ferromagnesian mineral in 4668, 4669, 4691, 4693, 4695, 4708 and 4684, which are rocks from zones of contamination in the quartz monzonite. In 4713 hornblende contains biotite inclusions. Tremolite occurs in a few cases as plumose groups (4703 and 4694).

Diorite Porphyry

Diorite porphyry apophyses, sills and dykes occur within the granitic mass and penetrate the country rocks up to 75 feet from the contact zone. As mentioned above it is thought that they result from the injection of more basic phases of granitic magma. They cut the aplite dykes, and therefore they are slightly younger than the quartz monzonite massif and aplite dykes.

At 910,180-602,250 a diorite porphyry dyke intrudes a central portion of the quartz monzonite batholith . It is 20 feet wide and at least 150 feet long. A similar dyke at 903,330-610,850 intrudes the marginal zone of the batholith, and during its

injection it plucked off rock fragments from its confining walls of country rock. Some xenoliths still have sharp margins; in others the margins are diffuse, and they are represented by concentrations of ferromagnesian minerals.

The diorite porphyry is a dark basic rock, showing light phenocrysts of felspar and long facets of hornblende laths.

Slides 4682 and 4717 are porphyritic with phenocrysts of plagioclase and hornblende (4717). Euhedral phenocrysts are corroded and in 4717 some myrmekitic texture is present. Plagioclase is more basic than that in the quartz monzonite and usually approaches labradorite in composition. Zonal bands in phenocrysts of 4682 alternate in composition. Felspar constitutes between 40 and 50 per cent of each slide.

Hornblende is the only ferromagnesian mineral, and alteration to epidote is common. In 4682 indistinct diopsidic cores contain alteration rims of tremolitic amphibole. Relative abundance of ferromagnesian minerals is between 25 and 50 per cent.

Quartz, when present, may occur as insignificant interstitial grains. Small quantities of magnetite occur in 4698 and 4682.

The rocks are diorites, or a late intrusive derived from a specialized basic phase of the original granitic magma, forming apophyses to the main granitic mass.

The Relation of the Quartz Monzonite to the St. Marys Porphyrite

At first appearance the quartz monzonite porphyry, which generally occurs marginal to the quartz monzonite mass (892,775-605,900), appears to have close textural similarities to the St. Marys Porphyrite. It differs in the type and proportion of ferromagnesian minerals present and it also contains numerous potash felspar phenocrysts.

Twelvetrees (1911) noted that hypersthene phenocrysts are abundantly developed in marginal zones of the quartz monzonite, and quoted the Beulah mine occurrence as an example (Tas. Mines Department Slide No. 224, A1Q15). Probably for this reason he considers the St. Marys Porphyrite a "border facies of the normal granitite", that is, Coastal Range quartz monzonite porphyry at the Beulah Mine. In the sections examined from Beulah mine area by the present writer, no hypersthene was seen (4766, 4733 and 4736). Hypersthene has not been observed associated with any phase of the granitic rocks, and the ferromagnesian minerals present are always biotite and hornblende.

In this paper, therefore, the St. Marys Porphyrite is considered a later mass distinct from the quartz monzonite massif, and is dealt with separately below.

Late Quartz Dolerite Dykes

Long, narrow basic dykes cut the Scamander succession in the vicinity of the quartz monzonite intrusive. The occurrence on the coast at 903,650-611,050 intrudes both the quartz monzonite and the country rocks. A 25 foot dyke at the Great Pyramid Copper Mine occurs in the country rocks (4762), and the occurrence at 898,600-603,600 is an intrusive of the same rock type (4716).

The dolerite is a fine dark-grey rock sprinkled with glistening facets of pyroxene and laths of felspar, and pyrite grains are scattered throughout. In section the rock has uniform texture and mineral composition. The fabric is intergranular to sub-ophitic. Small anhedral grains of pyroxene are badly fractured and have a grain size averaging about 1 mm. It is a light-green non-pleochroic clino-variety, of which some grains show alteration to fibrous amphibole. It constitutes about 50 per cent of each slide.

Plagioclase is seen as laths of about 2 mm. in length, which are invariably too altered to determine their composition. It shows twinning according to the albite law and has maximum extinction angle of about 15° (4762). Since the plagioclase grains have a low relief its composition approaches albite. Its relative abundance is 40 per cent.

Pyrite predominates among the remaining minerals and occurs as small and irregular grains abundantly scattered throughout the slide. It constitutes 15 per cent of slide 4762, but in 4761 there is only 5 per cent. Some magnetite is present. Quartz is relatively abundant, about 10 per cent occurring in groups of intergranular grains of 0·2 mm. size. Numerous fine apatite splinters, and grains of biotite and sphene, are frequently present. Biotite shows iron staining.

Alteration of the primary minerals is marked. Both amphibole and biotite are derived from the alteration of the pyroxene, and fibrous amphibole is associated with radiating clusters of chlorite. Up to 15 per cent of the slides may be tremolite and perhaps 5 per cent may be epidote and calcite, formed at the expense of original basic plagioclase in the development of albite. In all, accessory minerals and alteration products constitute about 30 per cent of the slides.

These altered quartz dolerites can be compared with altered dolerites at Hartley, New South Wales, described by Joplin (1937).

The slides show that the dyke rock is an altered quartz dolerite type preserving its original texture, although it lacks true ophitic fabric. It has undergone mainly low grade thermal metamorphism and associated stress effects are minor. The abundance of iron ore, quartz and well distributed apatite are unusual features.

The dyke rock was intruded after the emplacement of the granitic rocks, and probably represents the final igneous activity. It was possibly in the later stages of granitic consolidation that cooling of the doleritic magma underwent such autometamorphic and deuteric changes.

The St. Marys Porphyrite

The St. Marys Porphyrite was described by W. N. Benson for Twelvetrees' (1911) report on the Scamander area. He referred to it as a granitite porphyry of the St. Marys Pass. Subsequent more detailed work has shown that it is probably a porphyrite, under which heading it is now described, though it may be a dacite, as is discussed later.

The St. Marys Porphyrite crops out in the southern-most part of the area, south of an east-west line through Falmouth. Thirteen square miles of this igneous mass occur within the area under review, and the remainder extends beyond the southern limit. Only three miles of contact between the St. Marys Porphyrite and the Scamander succession occurs within the area and this represents only one tenth of its circumference. The contact has not been examined outside the area.

Contact relationships and Their Significance

The contact exposed between 885,275-599,925 and 885,950-601,975 approximates to a contour around ridges and spurs along which it intersects with the present surface of erosion. This contact relationship indicates the igneous mass has a floor gently sloping southwards at about 15 degrees.

The transgressive contact between the porphyrite and the adjacent sediments cuts straight across the ridge between 886,000-610,250 and 886,000-601,475. This apparent plunging discordant contact is similar to that of a granitic batholith. The projection of this transgressive contact line in a westerly direction is seen to intersect distinct physiographic depressions in other north-trending spurs. If the porphyrite has a floor these spurs should be capped with porphyrite, but those intersected by the contact contain no such capping. This suggests that a fault may be responsible for the transgressive nature of the contact.

Transgressive relationships are of limited occurrence and, in general, contacts indicate that the intrusion has a floor of Scamander Slate and Quartzite. The porphyrite was emplaced as an intrusive sheet or flow after regional folding of the Scamander succession and has not been subsequently folded.

No Scamander sediments were seen between the porphyrite and the overlying Permian sediments, nor were they seen exposed as inliers within the porphyrite. Contacts on Rays Hill and St. Patricks Head are between Jurassic dolerite and St. Marys Porphyrite. Hence, if the porphyrite is a sheet intrusive, it was uncovered before Permian time and the Permian sediments were deposited directly on top. They have since remained roughly horizontal. and if the porphyrite proves to be a dacitic flow, tilting occurred before the Permian sedimentation.

Estimated Thickness of the Porphyrite

Because there is no evidence of compound or multiple emplacements, there are certain upper limits of thickness beyond which the existence of a simple viscous flow would be exceptional Consideration must therefore be given to the thickness of the igneous mass, for this may be diagnostic in identifying the igneous forms on physical grounds. If the porphyrite is an intrusive sheet its thickness would be governed by the capacity of the Scamander sediments to accommodate the magma, an inestimable factor on present knowledge. The thickness would not significantly eliminate the possibility of its being a sheet, as it would if it is a flow.

Estimation of thickness can only be established approximately. There is at least 1500 feet difference in altitude between the floor of the mass at German Town and that at Falmouth. If three major faults of the north-west system progressively down-stepped the igneous mass towards the coast, then east flowing streams could deeply dissect a relatively thin igneous mass without exposing the underlying Scamander Slate and Quartzite.

In the south-west corner of the area around German Town, the difference in altitude of the floor contact and the highest outcrop of the igneous mass, provided no fault intervenes between the two, would give another rough estimation of minimum thickness.

From the above estimations it is probable that, if the porphyrite was a flow, it would be a single dacitic outpouring at least 500 feet thick.

Other Field Observations

Joints are more pronounced in the contact zone, where, usually, a series of parallel breaks has developed in the porphyrite. At 885,950-601,975 jointing planes strike 155° at 32°SW. Central regions of the porphyrite show mural jointing more characteristic of a granitic outcrop.

Xenoliths occur throughout the igneous mass, but only the larger ones remain in coastal zones. The coastal exposure at 884,525-600,225 shows abundant xenoliths in the porphyrite. Small inclusions of slate and quartzite fragments from the Scamander succession were incorporated into the magma. These can be recognized in marginal zones, but often as a result of their advanced stage of assimilation they commonly become chloritic clots in the central zones.

No apophyses were seen associated with the porphyrite, and no mineralization accompanied its emplacement.

Petrography

The porphyrite is a blue-grey rock with porphyritic texture, containing phenocrysts of quartz, felspar, pyroxene, biotite and sparse hornblende. It appears to be remarkably homogeneous in both texture and in mineralogy. Grain size varies systematically throughout the mass, ranging from porphyritic in the marginal zones to medium even-grained in the more central portions. Quartz and felspar phenocrysts measure up to 5 mm. in size and ferromagnesian minerals, including hypersthene, have a maximum grain size of 2 mm. Sometimes euhedral phenocrysts of plagioclase and quartz occur, but more commonly they are sharply angular fragments derived from shattered phenocrysts more characteristic of a pyroclastic rock. Hence, in many cases the texture of the rock is typically volcanic. Corrosion and pseudo-inclusions are common, particularly in quartz and felspar phenocrysts. This is especially noticeable near the margins of the igneous mass, but it is also a feature of more central zones where much hypersthene is altered to amphibole. In some cases the groundmass has penetrated along cleavage planes of biotite, forcing biotite flakes apart and causing them to flex.

In the slides of marginal rocks 4670, 4654 and 4657 flow structure on a microscopic scale occurs around partly assimilated argillaceous rock fragments. This structure is not apparent in field exposures. Marginal slides contain hypidiomorphic phenocrysts in a crypto-crystalline groundmass. In the central portions the groundmass consists of fine interlocking grains of quartz and felspar, and the fabric appears to be somewhat metamorphic, probably because consolidation was slower than in the contact portions.

In 4652, grains adjacent to fractures show signs of strain. Invariably the cryptocrystalline groundmass in the contact zone is fractured by numerous irregular cracks, which probably result from strains set up in the process of consolidation.

In the central zones small grains of quartz are included in felspar phenocrysts. Felspar is often zoned, and these zones alternate with little compositional difference between them and do not show gradational changes from basic to more acid towards the margin. The composition of plagioclase approaches labradorite Ab_{45}, An_{55}, and phenocrysts constitute about 27 per cent of the rock. Twin lamellae are invariably ruptured.

Staining tests (Chayes, 1952) did not reveal the presence of any potash felspar, though some may be occluded within the fine groundmass.

Quartz is relatively abundant as colourless euhedral grains and angular fragments and is invariably badly cracked. The average grain size is a little larger than plagioclase and it forms 26 per cent of the rock.

Biotite is moulded around hypersthene crystals or is intimately associated with magnetite grains. It develops in cracks which probably result from stresses associated with the emplacement of the magma. It is slightly more abundant than hypersthene and constitutes approximately 5 per cent of the rock.

Hypersthene is present in both marginal and central zones, as prismatic and euhedral crystals up to 2·5 mm. in size. Most grains are cracked, and have reaction rims of amphibole, with similar alteration along the cracks in grains. Some grains are enveloped by plagioclase.

Magnetite and a little apatite occur as accessory minerals, and numerous inclusions of clinozoisite within the felspar grains result from its alteration. The groundmass forms about 37 per cent of the slides, and consists, where it can be resolved, of quartz and untwinned felspar.

Form of Emplacement of the Porphyrite

From the above petrological evidence there seems little doubt that the porphyrite magma was partly crystallized at depth before it was emplaced in higher levels of the earth's crust. An intratelluric origin for the phenocrysts present is shown by a number of features. The fractured and fragmentary nature of many phenocrysts, especially felspar and quartz, accompanied by ruptured twin lamellae and bent biotite flakes, are all indicative of strains imposed on these mineral grains during the process of magma emplacement. The immunity of some fractures in mineral grains to corrosion by the liquid groundmass suggests that these fractures were formed at a late stage of consolidation.

The metastable state of the magma after emplacement in the near surface environment is shown by the corroded nature of felspar and quartz phenocrysts. Rapid cooling forestalled chemical readjustment and also sealed other evidence before significant changes could occur. Consequently, in the contact zones microscopic flow structure and cryptocrystalline groundmass can be seen, as well as the somewhat metastable mineral assemblage.

Contact alteration induced by the porphyrite in the adjacent Scamander Slate and Quartzite, discussed previously, was very slight or negligible. This feature accompanying such a large magmatic emplacement strongly suggests a rapidly cooling contact surface, as would be expected between a flow and its basement rocks.

The mineral assemblage of quartz, labradorite and hypersthene is not uncommon in andesitic flow rocks. The magma seems to have been extremely homogeneous. The abundance of quartz is exceptional and indicates that the composition is dacitic rather than that of a quartz-hypersthene andesite. Another feature is the absence of potash felspar.

It is difficult under the circumstances to name the rock precisely. The igneous form of the porphyrite has not been conclusively established yet, but present indications are that it has a floor. Microscopical examination strongly supports a flow origin for the rock and, if so, it is dacitic; but present field evidence is insufficient to prove this. Hence, if it is a near-surface discordant sheet, it could be referred to as a quartz-hypersthene porphyrite.

The Age of Igneous Rocks—Discussion

The granitic rocks and the St. Marys Porphyrite cannot be accurately dated: they are unquestionably Palaeozoic, and probably either mid-Devonian or lower Carboniferous. This conclusion is reached by comparison with similar occurrences in other parts of the State and Eastern Australia, especially Victoria, and by the fact that the quartz monzonite intrudes sediments considered, on their poor fossil remains, to be of upper Silurian or lower Devonian age. The leucocratic granite phase of St. Helens Point—aplite and diorite porphyry intrusives—although slightly younger than the quartz monzonite, are co-magmatic. The post-granite quartz dolerite dykes probably represent the last phase of this igneous cycle. They may have been intruded during the later stages of consolidation of the main granitic massif.

The diagnostic differences between Tabberabberan and Kanimblan acid intrusives of Eastern Australia are outlined by David (1950). The Devonian or Tabberabberan granitic rocks are considered to be adamellites introducing very little mineralization, perhaps some copper, lead and sil-

ver. They were preceded by co-magmatic porphyries and porphyrites, a few of which contain hypersthene. The intrusions were biotite and hornblende granitic rocks of a subsequent type, but so were the Kanimblan granites.

In north-east Tasmania present evidence strongly suggests that the St. Marys Porphyrite follows granitic emplacement with perhaps an interlude of erosion after the folding of the Scamander Slate and Quartzite. It was definitely emplaced before Permian sedimentation. The granitic intrusion was a subsequent type containing biotite as the ferromagnesian mineral. The Coastal Range quartz monzonite contains restricted zones of marginal porphyry without hypersthene. It introduced tin, tungsten, bismuth, molybdenum, copper, gold, silver and lead.

The possibility of two ages of granitic emplacement in the area cannot be completely overlooked, and indeed, Thomas (1943) believes this to be so. He considers that the tin granite is a separate intrusive; but present field and petrological work provisionally indicates that the granitic rocks belong to one intrusive cycle and the different leucocratic and contaminated intrusive phases which accompany the quartz monzonite intrusive are comagmatic.

Similar granitic activity in other parts of the State is considered mid-Devonian (Hills and Carey, 1949), and on the argument of uniformity, the granitic occurrence in north-east Tasmania could be considered of the same age. This means that the St. Marys Porphyrite was probably emplaced at a time slightly later than middle Devonian.

Dolerite of the Mt. Nicholas Sill

Tholeiitic dolerite occurs in the south-west corner of the area constituting the greater part of Rays Hill at German Town. It intruded the consolidated Permian sediments as dykes and sills in the Jurassic time, resting with discordant relations on the St. Marys Porphyrite and the Scamander Slate and Quartzite. Sills of dolerite occur both at the top and at the base of the Permian succession.

The texture of the rocks is ophitic and intersertal with porphyritic texture in the contact zones showing phenocrysts of enstatite and pigeonite (4648). A little interstitial quartz and alkali felspar in micrographic intergrowth forms part of the mesostasis.

Plagioclase occurs mainly as fine laths, but occasional stout prisms are seen, and grain size grades up to 0·25 mm. Twinning according to both the albite and Carlsbad laws indicates the composition ranges from andesine Ab_{55} An_{45} to labradorite Ab_{40} An_{60}, and in zoned crystals the outer zone is the more calcic variety. Zoning is poor, but as many as three zones have been seen, each differing in composition from the next innermost zone by about 10 per cent anorthite. In 4648 plagioclase constitutes about 50 per cent of the slide.

The average grain size of pyroxene is about 1 mm. Grains and prisms of pigeonite have been moulded on felspar laths, characteristic of ophitic textured rocks. Many enstatite phenocrysts have a reaction rim of clinopyroxene. Orthopyroxene appears to be restricted to the contact margin, but clinopyroxene occurs in all levels of the sill including the contact zone (slide 4648). The pyroxene makes up the remaining 50 per cent of the slides, since the proportion of minor constituents is very low.

Rock 4648 comes from the chilled margin at the contact with the St. Marys Porphyrite. In contact zones enstatite is the predominant pyroxene constituting 40 per cent of the slide, and has a 2 V of about 75°. The remaining pyroxene, pigeonite, has a 2 V between 0° and 30°. It characteristically shows herringbone structure, especially in the twinned crystals, and in the more central and coarser portions of the sill. It is the essential pyroxene. Bronzite occurs exclusively near the margins, hence this intermediate type was the first pyroxene to crystallize. Augite is also present in some slides, and therefore a fairly complete representation of the pyroxene solid solution series occurs within the sills. Augite grains are about 1 mm. size. Accessory minerals include biotite and iron ore.

The minor constituents quartz, alkali felspar, mica and amphibole are not seen in contact slides. Also, iron ore is scarce and grains are small in these slides, but become larger in more central zones. Quartz frequently occurs in higher portions of the sill as interstitial grains in the mesostasis, and occasional light to dark-brown grains of amphibole occur in zones other than the contact zones.

Secondary alteration of the pyroxene forms chlorite and a little associated iron ore. Chlorite is well developed as green fibrous growths in partings or as alteration rims to the pyroxene grains. Other secondary minerals include amphibole and calcite.

These features are in keeping with a tholeiitic dolerite magma homogeneous in texture and composition. As indicated by Edwards (1942), the magma was essentially liquid at the time of intrusion, although crystallization had begun, as is shown by the phenocrysts of orthopyroxene in the fine groundmass of the chilled margin (4648). In the Mt. Nicholas sill crystallization was slightly more advanced before intrusion than it was in many other similar sills in the State, and Edwards (1942) has shown that phenocrysts of the enstatite are larger and more abundant than in other localities, and that the rock shows a higher MgO content.

Contact metamorphism in the immediate contact sediments resulted only in minor localized changes.

STRUCTURE

Structural considerations must necessarily be conjectural owing to the present restricted knowledge on the stratigraphy of the Scamander Slate and Quartzite. The paucity of suitable exposures for structural and stratigrapical analyses leaves the structure obscure. Its complexity is no doubt accentuated by the frequency of minor breaks, and the monotonous regularity of the sedimentary succession in lithology and strike measurements. The location of major and minor faults proves difficult for the reasons mentioned, and in the absence of marker horizons determination of fault displacement is impossible.

The paucity of outcrop of Scamander Slate and Quartzite for structural analysis is due, on the one hand, to the masking effects of inherent short jointing in the stratified and indurated rock types, causing their outcrop to disintegrate, and shed rock debris concealing all structural features beneath it; and on the other hand, to the barren nature of massive quartzite outcrops. Only stratified coastal and road cuttings are available for structural measurement.

The initial structural and stratigraphic analysis of the Scamander Slate and Quartzite will have to be resolved outside the area under review and then extrapolated to this area.

Jointing

Regular jointing is a prominent feature. Not only does it characterize the brittle zone of deformation, where it is pronounced, but it is superimposed also on the plastically moulded rocks adjacent to the quartz monzonite.

Joints in a particular locality differ slightly in direction and these variations probably reflect slight changes in the physical properties of the rock types. In general, joint directions are consistent.

Analysis of jointing in the coastal exposure one mile north of Diana Basin (903,490-610,880 to 903,650-611,050) suggests that it belongs to one system. Fracture has occurred in three directions, including that parallel to the bedding. These are (1) 190° (2) 245° and (3) 305°. A number of other minor directions of failure developed, probably in sympathy with the major breaks.

Slight lateral displacement has occurred along some joint directions, particularly along 205°. Such breaks displace aplitic veins and apophyses from the adjacent granitic intrusive. Other joint directions may be older than these post-granitic breaks, since parallel folding of thinly bedded strata in the brittle zone would result in tension cracks developing in crests and troughs of folds.

Epeirogenic movements in the lower Tertiary probably imposed some jointing on the rocks of the area, and undoubtedly the Permian was jointed as a result of this gravitational readjustment. The relationship of jointing in the Scamander succession to that in the Permian rocks could not be established, but it is apparent that the intensity of jointing in the Scamander Slate and Quartzite is far greater.

Folding

The oldest structural features were developed when the Scamander succession was regionally folded and then injected by a granitic magma. In the contact zone the sediments were moulded into intricate folds and contortions, and evidently reached a sufficiently high temperature to be deformed plastically into similar type folds. A localized occurrence of this type of folding can be seen in the coastal outcrop one mile north of Diana's Basin. Away from the immediate contact zone folding is close, but broadens rapidly in more remote areas. Deformation in this brittle zone has resulted in parallel type folds (Hills, 1940) ruptured by numerous minor breaks, especially in the fold crests and troughs.

Along the coastal outcrop mentioned above, the closely parallel folded strata are steeply dipping and have a regular strike of 125°. In the Upper Scamander road sections (891,550-604,050 and 891,650-604,000) moderate to steeply dipping Scamander Slate and Quartzite show broader parallel folds and strike between 10° and 20°. Dips change systematically from 15° to 50°W, and a few openly folded anticlinal structures can be recognized. The crests of most folds have been eroded, so that few complete folds were seen in this area.

This consistent westerly dip suggests either that folds are repeatedly overturned from the west or that there may be many repetitions due to folding and faulting. The only easterly dip recorded was in the Scamander quarry where the strata dip at 60°. The possibility that anticlinorial and synclinorial structures are developed in the area seems doubtful.

Faulting

Faulting in the lower Tertiary affected the whole area. The extent of this faulting is demonstrated by the down faulting of a small residual of Permian at (884,250-603,550), mentioned previously. This outlier of Permian in the Falmouth area has been downthrown relative to its equivalent stratigraphical horizon at German Town by a series of north-west-trending faults progressively down stepping it eastwards, resulting in a cumulative vertical displacement of 1300 feet. Faulting is not pronounced along the St. Marys Porphyrite contact from 885,275-599,925 to 886,000-601,250, but from 886,000-601,250 to Falmouth all north-east trending valleys are fault valleys.

There is a number of difficulties in analysing the lower Tertiary fault system. As mentioned, topography is controlled to a certain degree by faulting, and this helps in defining linears on the aerial photographs, but only those that cut igneous contact zones can be recognized in the field. Hence the present representation of faults and trends on the map is misleading, for the density of the faults is greater in these contact zones. Those occurring completely within the Scamander Slate and Quartzite, or within the granitic rocks, may be just as dense, but are hidden. Faults which have been mapped are plotted with vertical displacement, lacking evidence to the contrary. Faults in the Orieco copper workings all dip at high angles, averaging 80° SW. Analysis of the faults mapped and inferred from photo-interpretation indicates that two directions of failure are favoured, and both belong to the same fault system.

In the fault system of the southern part of the area, fault trends in St. Marys Porphyrite occur in two directions: (*a*) N.W. (*b*) N.E.

In the eastern and north-eastern regions of the area similar trending faults cut the Coastal Range quartz monzonite and the marginal zones with the adjacent sediments:

(*a*) N.W. (*b*) N.E.

In the western zone, which consists essentially of Scamander Slate and Quartzite, Henderson (1941) records faults of an older system which trend 315° and this direction includes the mineralized channels of the Ringarooma P.A., Orieco and Dunn's prospects. He says that shafts of the Orieco appear to be located on a prominent cross fault, while a second group of faults strikes 190° and dips 70°E, and the remaining faults are at 280°, but are not very extensive in this direction.

Other Structural Events

If the St. Marys Porphyrite proves to be a flow, then the possibility that it has been tilted before Permian sedimentation must be recognized, and it would be expected that jointing of the adjacent country rocks would result from this. There is no other apparent structural evidence in the area to suggest this fault block tilting took place.

In the south-west corner of the area, the structure of the Permian succession has been controlled by the intrusion of dolerite and concomitant faulting. The upwelling magma rotated and differentially displaced Permian sedimentary blocks relative to one another. The Permian beds dip at low angles, 0 to 5°, probably owing to a combination of depositional dips and tilting in the dolerite magma. Jointing is pronounced in places, and this results, as mentioned above, from the Tertiary faulting.

ECONOMIC GEOLOGY

Mineralization in the area resulted in the introduction of molybdenum, bismuth, tin, tungsten, copper, silver, gold and lead. After the emplacement of the granitic rocks, possibly the first joint direction to develop after its consolidation was that favoured by the mineralizing solutions for ore deposition.

The biotite-quartz monzonite is the predominant granitic rock of the area. It is intruded by minor quantities of a slightly later phase muscovite granite. Exactly which intrusive brought in tin is not known. Thomas (1943) suggests that two granitic intrusives exist, one of which is tin-bearing.

Primary Tin-Tungsten

The general axis of tin-tungsten mineralization is roughly north-south. This line of primary mineralization persists from 905,150-600,940 through to the Upper Scamander tungsten deposits, two miles west of the Pyramid. Henderson (1941) says that structural relations indicate a regional break in which the east block moved north along this line.

Most probably the greater part of the wolframite has been removed by erosion; and granitic rocks are either close to, or actually exposed at, the surface. Consequently only minor quantities of high temperature mineralization remain, and the original deposits are now represented by secondary alluvial deposits.

The presence of copper in the Orieco workings, although mainly secondary, perhaps indicates that here a rather thicker sedimentary cover exists on the granitic rocks.

The primary tin-tungsten deposits occur as veins in the granitic rocks.

On Constable Creek (905,150-600,940) tungsten mineralization may occur in the hood of a cupola or an exposed high of the granitic intrusive. A little crystallized cassiterite also occurs in the joint planes of the adjacent quartzites. These sediments strike approximately north-west and the granitic rock is jointed in the 45° and 105° directions. About 40 mineral veins occur and they all strike 285°.

In 1952 the main lode had been opened up a distance of 500 feet and in places proved to be 25 feet deep. The veins bulge and pinch along their length and in the main vein the width varies from less than a foot to six feet in one place. The other veins are mineralized to differing degrees, but are of minor size in comparison with the main one. Minerals present include wolframite, scheelite, molybdenite and bismuthinite in a gangue of quartz, arsenopyrite and pyrite.

Up to 1952 one ton of wolframite had been extracted from the main vein. The deposit averaged approximately one per cent; the wolframite occurs generally in small isolated concentrations, intimately associated with molybdenite in the gangue of essentially quartz. The hanging and foot walls are of hydrothermally altered aplitic material, a quartz muscovite rock.

Alluvial Tin

Most of the tin ore from north-east Tasmania has been won from alluvial deposits which occur as leads along comparatively well defined courses. The main group of tin fields occurs a little to the north-west of the area under review.

Tin is worked on different levels of lead development, mainly superficial ones overlying Thureau's Lead, subsidiary leads, or along the present day streams in the vicinity of Thureau's Lead. Some tin is worked from decomposed granite *in situ*.

Deposits range up to 20 feet in thickness, but usually average between 5 and 12 feet of probable fluvial deposits consisting of clays, sands, gravels and unconsolidated ferruginous and argillaceous quartz granule conglomerates.

The bottom is sometimes decomposed granite, as mentioned, but generally it is clay or gravel with the lead, in which case it is locally referred to as " marine bottom ".

Throughout the gravel profile there are definite horizons in which tin is concentrated, while the remainder is barren or uneconomical.

Tin in the cassiterite assays as high as 75·4 per cent and 1 to 1·5 per cent tungsten is associated with it in some pockets. Other minerals present, according to Nye (1933), are ilmenite, pleonaste, zircon and sapphire, &c.

The source of the tin is unknown at present, but some at least would be derived from the decomposed granite containing disseminated tin. The remainder would come from vein tin of unknown location, and conditions governing concentration have been discussed.

Copper

The copper deposits lie about two miles north, north-east of the Upper Scamander Bridge. The Orieco lode runs north-west for two miles from the western bank of the north arm of the Scamander River.

The occurrence consists of groups of parallel arsenopyrite — quartz-chalcopyrite veins with occasional development of zones of mineralized material on each side of the primary fissure. The veins occur in fissures of great length, along which differential movement is not extensive. The shoots of ore appear to pitch in a southerly direction.

The copper minerals have been leached to a depth of 200 feet, and the oxidized ores include cuprite, chalcanthite, azurite and malachite.

Henderson (1941) states that the chief concentrations of secondary ore occur as selvages on a wide formation of much kaolinized slaty lode material, and that mineralization appears to be confined to crush zones, particularly in the thinly bedded slates, and follows the many component fractures of the zone.

The structure of the west fault block is essentially an overturned south pitching fold, the truncated crest of which is composed of dense blocky sandstone and quartzites with occasional intercalations of thinly bedded slates. Few crush zones are developed on the eastern side of the main ore channel where thinly bedded slates are more apparent. Many crush zones occur in essentially blocky sandstones or quartzites, but no mineralization is associated with them.

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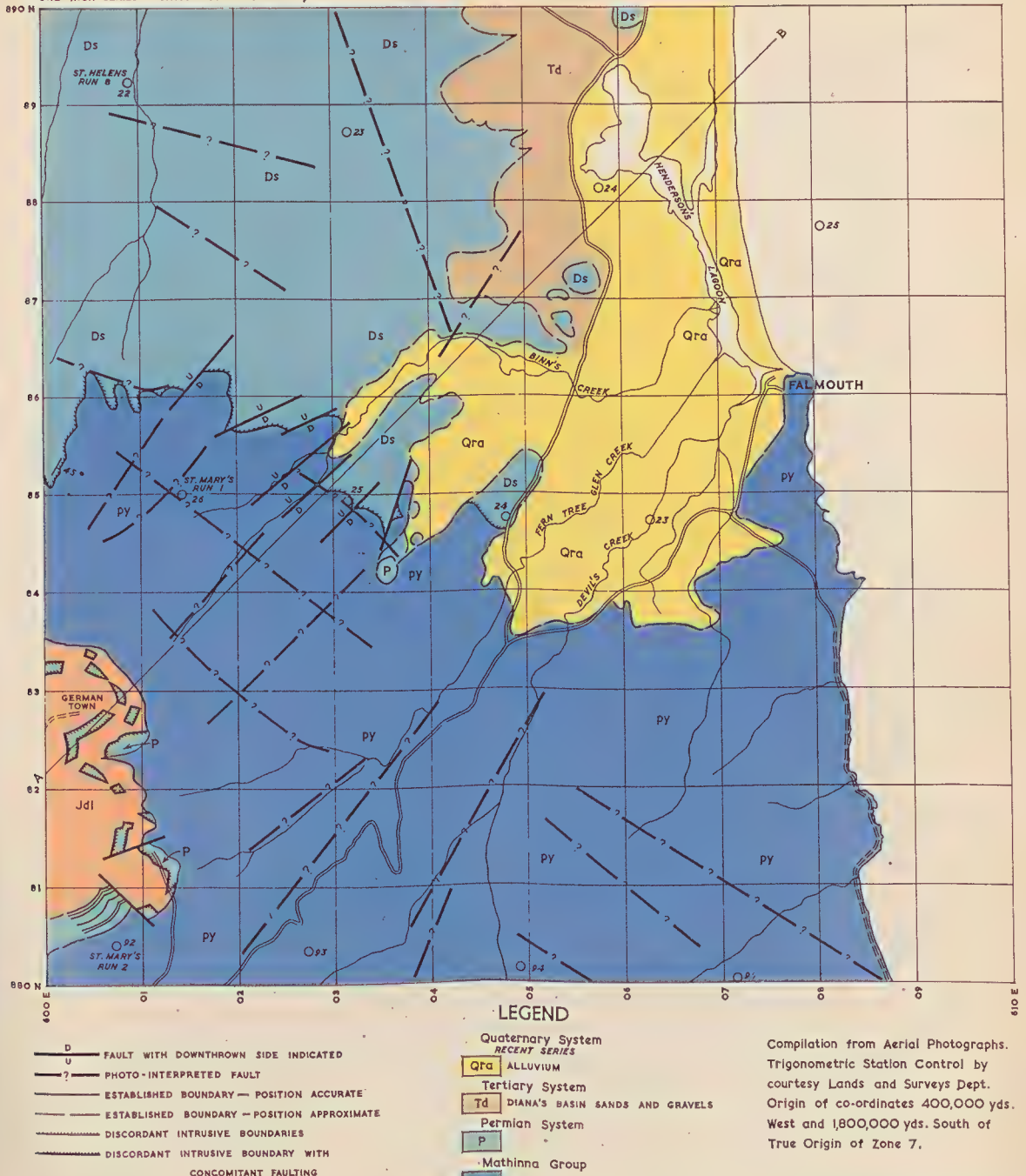
LOCALITY INDEX

	Quadrangle		S. Lat.	E. Long.
Coastal Range	St. Helens	41	41° 22′	148° 20′
Diana Basin (Inlet)	St. Helens	41	41° 23′	148° 18′
Falmouth	St. Marys	49	41° 29′	148° 16′
George Bay	St. Helens	41	41° 19′	148° 18′
German Town	St. Marys	49	41° 32′	148° 17′
Goshen	St. Helens	41	41° 17′	148° 6′
Hendersons Lagoon	St. Helens	41	41° 29′	148° 16′
Meadeas Cove	St. Helens	41	41° 20′	148° 14′
Moriarty Lagoon	St. Helens	41	41° 18′	148° 20′
Mount Nicholas	St. Marys	49	41° 32′	148° 12′
Paddy's Island	St. Helens	41	41° 24′	148° 19′
St. Helens	St. Helens	41	41° 18′	148° 14′
St. Helens Point	St. Helens	41	41° 17′	148° 22′
St. Helens Island	St. Helens	41	41° 21′	148° 20′
St. Marys Pass	St. Marys	49	41° 35′	148° 17′
St. Patricks Head	St. Marys	49	41° 34′	148° 19′
Scamander	St. Helens	41	41° 27′	148° 21′
Upper Scamander	St. Helens	41	41° 27′	148° 13′
Wrinkler's Basin	St. Helens	41	41° 27′	148° 20′

FALMOUTH



LEGEND

- FAULT WITH DOWNTHROWN SIDE INDICATED (D / U)
- PHOTO-INTERPRETED FAULT
- ESTABLISHED BOUNDARY — POSITION ACCURATE
- ESTABLISHED BOUNDARY — POSITION APPROXIMATE
- DISCORDANT INTRUSIVE BOUNDARIES
- DISCORDANT INTRUSIVE BOUNDARY WITH CONCOMITANT FAULTING
- 45° STRIKE AND DIP
- ROADS
- VEHICULAR TRACK
- TRACK
- PHOTO CENTRE

— SCALE —

0 1 2 3 4 5,000 10,000 FEET

0 1 2 MILES

Quaternary System
RECENT SERIES
- Qra ALLUVIUM

Tertiary System
- Td DIANA'S BASIN SANDS AND GRAVELS

Permian System
- P

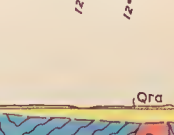
Mathinna Group
- Ds SCAMANDER SLATE AND QUARTZITE

IGNEOUS ROCKS
- Jdl JURASSIC DOLERITE
- py ST. MARY'S PORPHYRY
- Dc COASTAL RANGE QUARTZ MONZONITE

MAPPED AND COMPILED BY
K. R. WALKER 1953

Compilation from Aerial Photographs. Trigonometric Station Control by courtesy Lands and Surveys Dept. Origin of co-ordinates 400,000 yds. West and 1,800,000 yds. South of True Origin of Zone 7.

KEY MAP SHOWING MAGNETIC DECLINATIONS SECULAR VARIATION 7 MINS. PER ANNUM



GEOLOGY OF FALMOUTH

SHEET 6088

PHYSIOGRAPHY.

Two physiographic units occur in this area, a low, mountainous, early mature hinterland and a partially rejuvenated, youthful coastal plain. Drainage more or less radiates from the area around German Town and St. Patrick's Head. The streams are in mountain tract for about half their course and then enter valley tract in which they remain till they reach the sea. In the Scamander Slate and Quartzite the joints control the streams and in the St. Marys Porphyry streams are controlled by faults. The coastal plain ranges from 350 feet above sea level inland to 170 feet towards the coast. This plain is deeply dissected but the hills still carry a cover of sediment and hill levels are accordant. Still closer to the coast are the barred lakes, lagoons and swamps behind the beach ridges and beaches. South of Falmouth the coast is cliffed but to the north it is mainly long beaches, and the coast is comparatively straight. The Scamander River is considered to have originally flowed into the sea near Falmouth.

STRATIGRAPHY AND IGNEOUS ROCKS.

The basement rock in the area is the Scamander Slate and Quartzite. This formation is of unknown thickness and contains argillites and arenites of the sub-greywacke suite. North of the area it contains primitive vascular plants and fragmental marine fossils. It may be in part Silurian or Lower Devonian. The deposition of these beds was followed by folding, then intrusion of the Coastal Range Quartz Monzonite. Sometime later the St. Marys Porphyry was emplaced, perhaps as a lava flow. Tilting and erosion followed before deposition of the Permian sediments began. Several Permian formations are present and include a limestone and a glauconitic sandstone. Later, probably in the Jurassic Period, the Permian sediments were disrupted by dolerite intrusions.

Later faulting further disrupted the Permian and older rocks and after this the coastal plain and the sediments on it developed.

STRUCTURAL GEOLOGY.

The Scamander Formation is folded along axes trending N15°E to N20°E and generally somewhat overturned to the east. Where the base of the St. Marys Porphyry is exposed it is seen to be dipping 15° to the south. The Permian and Tertiary beds are virtually horizontal.

Faults affect the Scamander Formation, Coastal Range Monzonite, St. Marys Porphyry and the Permian sediments. These form a conjugate system, trending north-west and north-east. Some of these at least are post-Permian as the Enstone Park Limestone (Permian) occurs on Rays Hill and much lower topographically at Enstone Park. Faults associated with the intrusion of dolerite also affect the Permian beds near German Town.

POINTS OF SPECIAL INTEREST.

Permian Section on Rays Hill (600.5E.880.5N)

St. Marys Porphyry in St. Marys Pass (602.5E.880.5N)

Base of St. Marys Porphyry (602.2E.886N)

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GEOLOGY OF TASMANIA

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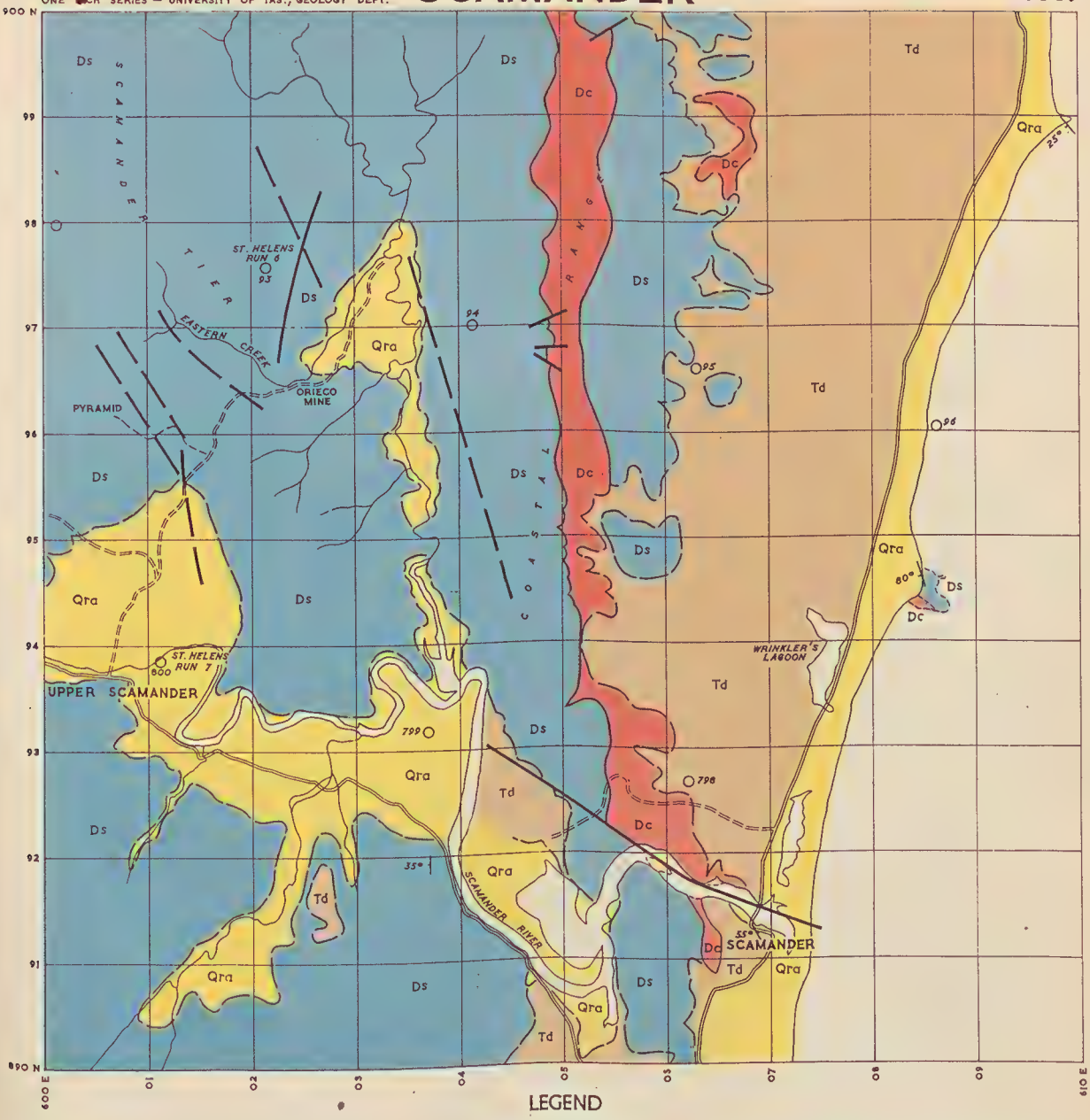
SCAMANDER

6089



LEGEND

Quaternary System

RECENT SERIES

Qra — ALLUVIUM

Tertiary System

Td — DIANA'S BASIN SANDS AND GRAVELS

Mathinna Group

Ds — SCAMANDER SLATE AND QUARTZITE

IGNEOUS ROCKS

Dc — COASTAL RANGE QUARTZ MONZONITE.

D/U — FAULT WITH DOWNTHROWN SIDE INDICATED

PHOTO — INTERPRETED FAULT

ESTABLISHED BOUNDARY — POSITION ACCURATE

ESTABLISHED BOUNDARY — POSITION APPROXIMATE

55° — STRIKE AND DIP

ROADS

VEHICULAR TRACK

TRACK

BRIDGE

PHOTO CENTRE

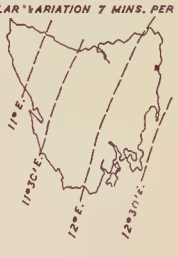
— SCALE —

0 1 2 3 4 5,000 FEET

0 2 MILES

Compilation from Aerial Photographs. Trigonometric Station Control by courtesy Lands and Surveys Dept. Origin of co-ordinates 400,000 yds. West and 1,800,000 yds. South of True Origin of Zone 7.

KEY MAP SHOWING MAGNETIC DECLINATION SECULAR VARIATION 7 MINS. PER ANNUM



MAPPED AND COMPILED BY

K. R. WALKER - 1953

GEOLOGY OF SCAMANDER.
SHEET 6089

PHYSIOGRAPHY.

There are three physiographic units in this area. The western-most one is characterised by Scamander Tier and the Coastal Range and is an area of late youthful or early mature topography drained dominantly by streams in their mountain tract. The exception to this is the Scamander River which is a drowned river in its valley tract. Further east still is the coastal plain with a veneer of gravels and sands up to a height of 350 feet. This is deeply dissected but still youthful. Near the coast this plain is succeeded by a strip of lagoons, swamps, marshes, beach ridges and long sweeping sandy beaches with occasional rocky headlands.

The western unit seems to have been part of an easterly dipping uplifted surface which locally reaches 1,500 feet high on Scamander Tier. Drainage in the western area has a trellised pattern, being controlled by bedding and prominent joints at right angles to it.

STRATIGRAPHY.

The oldest rock in the area is the Scamander Slate and Quartzite. This formation consists of slates, siltstones, quartzites, sandstones and sub-greywackes. Some banding is present. Depositional rolls, slump structures and cross-bedding occur. Fossils in this formation include primitive vascular plants and fragmental marine fossils.

The next formation is the Diana's Basin Sand and Gravel which caps the coastal plain. These reach a thickness of 150 feet and are up to 350 feet above sea level at which height a ferruginous granule conglomerate is common. No fossils have been found in the formation and it is regarded as Tertiary on physiographic grounds.

The youngest beds in the area are the dune and beach sands and river alluvium.

IGNEOUS ROCKS.

The Coastal Range Quartz Monzonite forms the axis of the Coastal Range where it intrudes the Scamander Slate and Quartzite with sharp contacts. Temperature of the intrusion was just enough to produce plastic deformation of the intruded rocks. The monzonite contains andesine, microcline, quartz, biotite and hornblende with some orthoclase, apatite, muscovite and other minerals in small amounts. Numerous textural variations occur; aplitic and pegmatitic veins occur associated with the main stock. Transgressing the quartz monzonite are dykes of diorite porphyry which also intrudes some of the aplites. The diorite porphyry consists essentially of labradorite and hornblende. Quartz dolerite dykes cut the Scamander Formation and the monzonite and may be late magmatic differentiates of the monzonite magma.

STRUCTURAL GEOLOGY.

The Scamander Formation is folded along axes trending N15°E to N20°E and usually overturned slightly to the east.

Faults with a north-easterly, easterly and south-easterly trend offset the monzonite contact but only by small amounts. A fault trending somewhat south of east displaces the contact of the monzonite, south side east, on the Scamander River and reduces the width of outcrop of the monzonite stock considerably suggesting a downthrow to the south.

ECONOMIC GEOLOGY.

The Pyramid, Orieco and Beulah Mines occur within this area. The Orieco deposit contains copper in the form of chalcopyrite in ore shoots in crush zones in thinly bedded slates. The Beulah Mine was worked unsuccessfully for silver. None of the mines is economically significant at present.

POINTS OF SPECIAL INTEREST.

Scamander Formation with fossils in cuttings on the Upper Scamander Road (604.000E.891.5N)

Scamander Formation marine fossils in quarry on south side of bridge over Scamander River (606.8E.891.6N).

Beulah Mine (606.3E.891.6N).

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GEOLOGY OF TASMANIA

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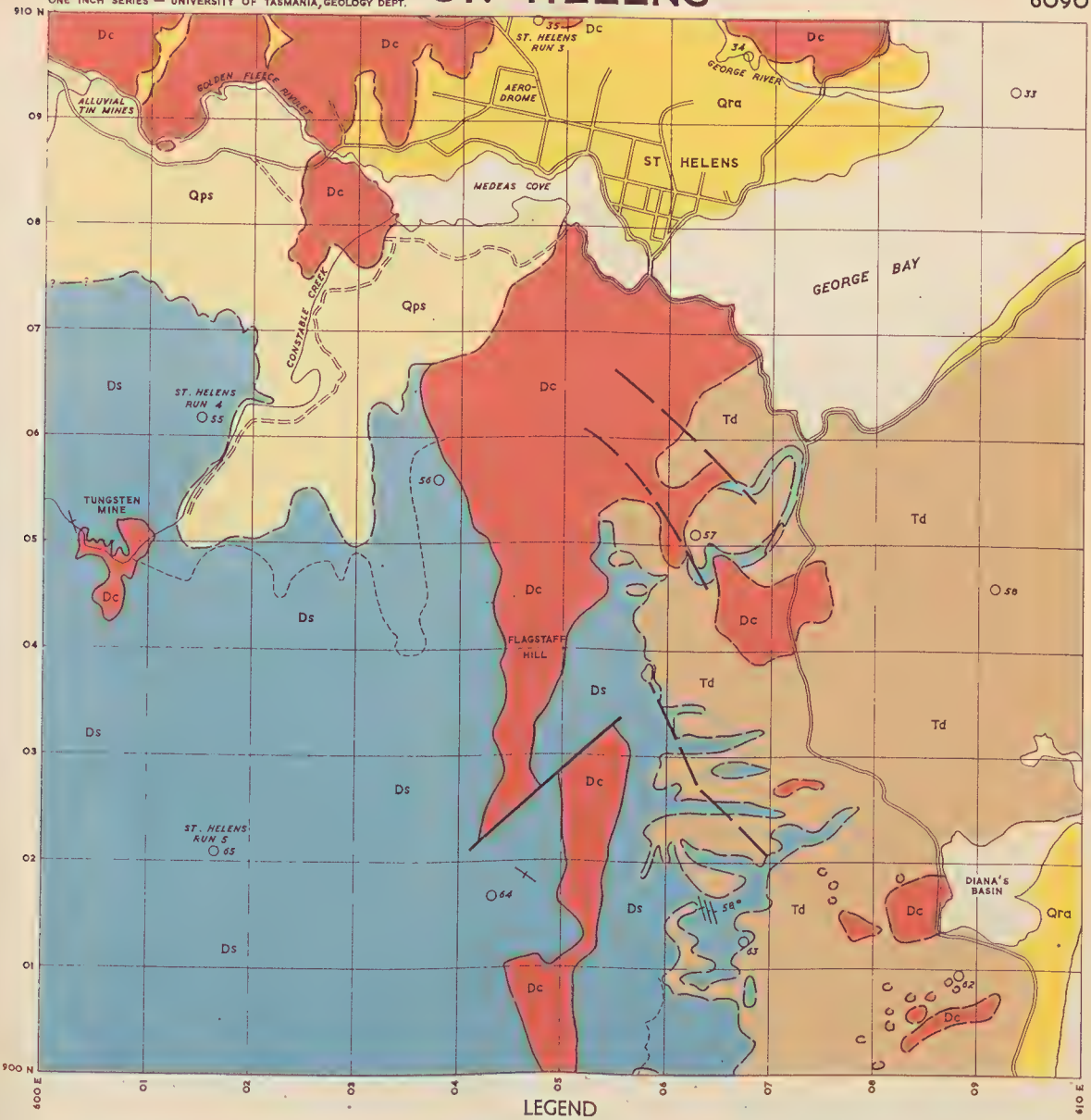
ST. HELENS

6090



LEGEND

D / U — FAULT WITH DOWNTHROWN SIDE INDICATED

PHOTO — INTERPRETED FAULT

ESTABLISHED BOUNDARY — POSITION ACCURATE

ESTABLISHED BOUNDARY — POSITION APPROXIMATE

STRIKE AND DIP

ROADS

VEHICULAR TRACK

TRACK

BRIDGE

PHOTO CENTRE

VERTICAL DIP

Quaternary System

RECENT SERIES

Qra — ALLUVIUM

PLEISTOCENE SERIES

Qps — ST. HELENS CLAYS AND GRAVELS

Tertiary System

Td — DIANA'S BASIN SANDS AND GRAVELS

Mathinna Group

Ds — SCAMANDER SLATE AND QUARTZITE

IGNEOUS ROCKS

Dc — COASTAL RANGE QUARTZ MONZONITE

— SCALE —

0 — 2 MILES

0 1 2 3 4 5,000 — 10,000 FEET

MAPPED AND COMPILED BY

K. R. WALKER 1953

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KEY MAP SHOWING MAGNETIC DECLINATIONS SECULAR VARIATION 7 MINS. P. A.

N

GEOLOGY OF ST. HELENS.
SHEET 6090

PHYSIOGRAPHY.

There are four physiographic units in this area. The south-west is an area of deeply dissected Scamander Formation and granite. This rises to about 1,500 feet in the west and is probably part of an uplifted surface dipping east. The streams in this area are in mountain tract and form a trellised drainage, the details of the stream courses being controlled partly by bedding but dominantly by jointing. The topography is late youthful or early mature. East of this is the coastal plain rising landward to 350 feet above sea level and covered with a veneer of sediments. This is dissected by streams flowing east to the sea which have cut valleys up to 150 feet deep. On its eastern boundary this drops sharply from 170 feet to the third unit, the lagoon and swamp area behind the beach ridges, the ridges themselves and the beaches. The coastline consists of long sweeping sandy beaches with rocky headlands and several islands off-shore. The coastal plain may have extended to the west and south-west of St. Helens up Constable Creek and Golden Fleece Rivulet. Around St. Helens itself is a fourth area only a few feet above sea level which is a flat alluvial plain.

STRATIGRAPHY.

The Scamander Formation occupies large parts of the area and consists of slates and quartzites for the most part. In the area to the south primitive land plants and fragmental marine fossils occur.

Unconformably on the Scamander Formation and Coastal Range Quartz Monzonite is the Diana's Basin Sand and Gravel. This forms a veneer on the coastal plain up to 350 feet above sea level and is at least 150 feet thick. In many places it is capped by a ferruginous granule conglomerate.

In the immediate vicinity of St. Helens Thureau's Deep Lead extends to 200 feet below sea level. The sediments in the Deep Lead and surrounding areas are called the St. Helens Clay and Gravel and contain some tin.

IGNEOUS ROCKS.

The only igneous rock in the area is the Coastal Range Quartz Monzonite with its associated differentiates. Contacts with intruded sediments are sharp but just north of Diana's Basin the intrusion has produced plastic deformation of the sediments. The monzonite contains andesine, microcline, quartz, biotite and hornblende with some orthoclase, apatite, muscovite and other minerals in small amounts. Numerous textural variations occur. Transgressing the quartz monzonite are dykes of diorite porphyry which consists essentially of labradorite and hornblende.

STRUCTURAL GEOLOGY.

West and immediately east of the Coastal Range the Scamander Formation has been folded along axes trending N15°-20°E and somewhat overturned to the east. On the coast north of Diana's Basin, however, the strike is consistently N55°W and the dip is very steep with some intricate overfolding to the north, some of the folds being recumbent and open to the south. Faulting can rarely be demonstrated but a north-easterly trending fault displaces the monzonite stock about a mile south of Flagstaff Hill (605E.902.8N).

ECONOMIC GEOLOGY.

Wolframite is being worked on the upper part of Constable Creek. It occurs in veins with quartz, scheelite, molybdenite and bismuth. The veins which are not more than 6 feet thick strike 285° and are mainly in the quartz monzonite but in places cut the country rock where some cassiterite is developed.

Thureau's Deep Lead has been tested and found to contain tin which has been worked in some of the subsidiary leads. At Goshen tin occurs in wash overlying granite and in the overburden. Some wolframite also occurs with it.

White clays occur in tin workings and on the southern headland of George's Bay.

POINTS OF SPECIAL INTEREST.

Intrusion of granite and folding on first headland north of Diana's Basin.

Sediments on southern headland of George Bay.

Tungsten Mine on Constable Creek.

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A TYPE SECTION OF THE PERMIAN SYSTEM IN THE HOBART AREA, TASMANIA

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(With 9 Text Figures)

ABSTRACT

An unbroken succession of Permian sediments about 1430 feet thick on the northern flanks of Mt. Nassau, about 10 miles north-west of Hobart, Tasmania, shows the following succession of formations from the base upwards: Bundella Mudstone; Faulkner Group including the Geiss Conglomerate, Rathbones Sandstone and Siltstone, Byers Sandstone, Jarvis Siltstone, Parramore Sandstone and Siltstone, Altamont Conglomerate and Fergusson Siltstone; Rayner Sandstone; Cascades Group including the Nassau Siltstone, Berriedale Limestone and Grange Mudstone; "Woodbridge Glacial Formation"; Risdon Sandstone and finally the Ferntree Mudstone. These range in age from Lower Artinskian to Kungurian. These formations, except the "Woodbridge Glacial Formation", are defined. The Faulkner Group consists of two cyclothems, recording two brief emergences, one soon after the other, in a time of general submergence. The Grange Mudstone and Berriedale Limestone are at least partly facies variants of one another. A notable feature is the presence of erratics, except in the two non-marine formations in the Faulkner Group, and this is perhaps related to the poor sorting, and mineralogical immaturity of the sediments and the angularity of most of the grains in all rocks. All of these features are considered as the result of glacio-marine deposition. The source area included granitic, sedimentary and regionally metamorphosed rocks.

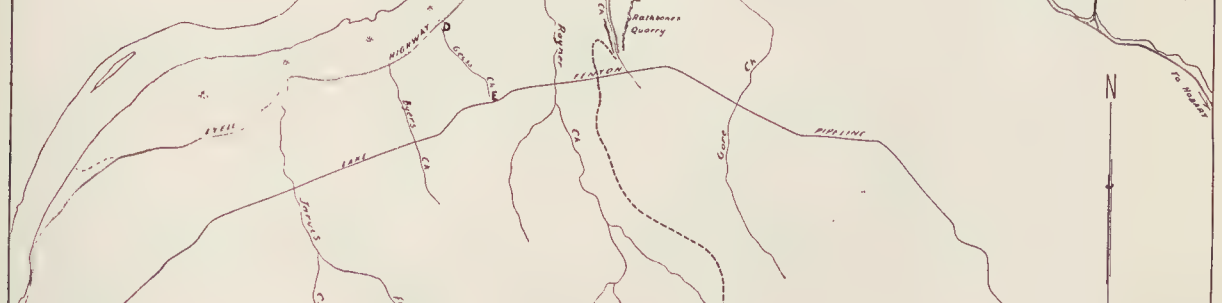


Fig. 1

N.B.—On the advice of the Nomenclature Board of Tasmania, the names of Parramore Creek and Rayner Creek should be transposed.

INTRODUCTION

Mapping of the Hobart district indicated that the Permian succession suggested by Lewis (1946) was inadequate for close mapping so that when a section was discovered which is not complicated by faulting, it was studied in some detail for use as a standard of reference. The type section lies between road level of the Lyell Highway from Rayner Creek to Geiss Creek and the base of the Knocklofty Sandstone and Shale (Triassic) on Mt. Nassau. It is all included on air photo Hobart, Run 1, No. 9744, of the Department of Lands and Surveys, Tasmania, and is shown on the map, text figure 1.

The section was initially taken from point A (see map) along Rayner Creek for a couple of hundred yards, then up the east bank across the present access road to the western quarry to the former access road to the eastern quarry and along and up this road to that quarry. From this quarry the section crosses Rayner Creek and goes up and along an old timber track which skirts the southern edge of the western quarry and goes on up the spur over the Lake Fenton Pipeline to the foot of the last slope up to Mt. Nassau at point B. All thicknesses in this section were measured by means of an Abney level as the beds have a very low dip. Attention should be drawn here to the more detailed sections of the Berriedale Limestone measured in the quarries on the eastern and western sides of Rayner Creek by Brill and published as section 4 of fig. 1 of Brill (1956). These sections were measured on the quarry faces with a tape and are thus rather more accurate than the general section. The authors' attention was directed by Mr. H. A. Bartlett to fossiliferous mudstones on the Lyell Highway at point C on the map. On investigation these proved to be well exposed and below the lowest beds in Rayner Creek. A section was therefore measured up from the gutter on the western side of the Lyell Highway just west of Parramore Creek at the eastern end of the road cutting and westwards along the cuttings to Geiss Creek and then up to Geiss Creek to the top of the well-exposed portion of the succession. The Bundella Mudstone in the road cuttings and in the lower part of Geiss Creek was measured with a steel tape but the creek section and road section are not connected by good exposures. They were joined by measuring up from the top exposures in the road cutting to the base of the Geiss Conglomerate, tracing this conglomerate around the hill slope and into the creek where the beds immediately below the Geiss Conglomerate are exposed and were measured. This leaves a gap in the section due to inadequate exposures. The beds in Geiss Creek from the upper part of the Bundella Mudstone into the Fergusson Siltstone are well exposed and were measured with a steel tape but the section above that was measured up the western hill slope to the Rayner Sandstone, back into the bed of Geiss Creek and along the creek bed with an Abney Level until good exposures of the Nassau Siltstone were reached when the tape was used again for a few feet and then the Abney Level was used to complete the section to point E. Co-ordinates quoted refer to the state grid on the 8-mile map (Lands Dept., Hobart).

The authors wish to acknowledge discussions with Professor K. G. Brill, Visiting Fulbright Professor at the University of Tasmania, and Professor S. W. Carey concerning stratigraphic methods and nomenclature. We are indebted to Mr. H. A. Bartlett for drawing our attention to the exposures of the Bundella Mudstone on the Lyell Highway. Finally we would like to acknowledge the assistance of Mr. A. H. Spry in checking mineralogical determinations in some cases.

HISTORY OF STRATIGRAPHIC NOMENCLATURE IN THE PERMIAN SYSTEM IN THE HOBART AREA

Darwin (1844) and Strzelecki (1845) were perhaps two of the earliest authors to deal with Permian rocks from the Hobart area. Later Jukes (1847) and Selwyn (1855) added further observations. The first author to deal at length with the Hobart Permian was Harrison in 1865 who noted that the colonists referred to the "Mountain Limestone" (now Berriedale Limestone) and this name was used, albeit informally, by Wintle (1865). In 1866 Gould formally proposed the first formational name for a Permian rock in this area when he suggested that the prominent spiriferous limestones around Hobart should be called the Mount Wellington Limestone to distinguish it from the Gordon Limestone of Ordovician age. There is little doubt that the limestone named thus by Gould is the limestone formation called Berriedale Limestone by Voisey (1938) and subsequent workers. Although it is clear that Gould's name has priority the later name will be used in order to avoid further confusion. The next major contribution was that of Johnston (1888) who described several sections in the area but used terms such as Lower Marine Series, Lower Coal Measures and Upper Marine Series to suggest correlations with New South Wales and names such as *Spirifer* Zone, *Fenestella* Zone and *Pachydomus* Zone to characterize the beds by their dominant fossil. However, he had earlier (1886) given formal names to some of these beds such as those at Porter Hill, the Porter Hill Beds, and the beds at the 3-mile post on the Channel Highway as the Lower Sandy Bay Beds. However, his usage of these names was not consistent and Porter Hill Beds was used in a different sense by him in 1888. The approximate usage of Johnston's terms will be considered under the appropriate formation heading. Johnston also seems to have laid the foundation of an error which has led all workers astray. He correlated the limestone at the shoreline at Lower Sandy Bay, i.e., Porter Hill, with the limestone at Cascades and Bridgewater (i.e., Mt. Nassau), which is now considered on stratigraphical, lithological and palaeontological grounds to be a distinct and higher formation, the Berriedale Limestone. By so doing he caused later workers to assume that the Grange Mudstone was above the Berriedale Limestone and separated from it by several hundred feet of sediment instead of equivalent to it as will be suggested later in this paper. This latter assumption confused Voisey (1938), Lewis (1946) and Banks (1952) and all workers in Tasmania and elsewhere who tried to make faunal correlations. It also led to

the idea of very great similarity in the faunas on all horizons and blinded workers to the differences between the faunas from different horizons.

The first worker to consistently use stratigraphic names for Permian formations in this area was Voisey (1938) who proposed formation names later used also by Lewis (1946). These names were in some cases not very clearly defined and the beds below the supposed Berriedale Limestone were covered only by a wide term "Snug Stage", synonymy of which will be considered later.

Establishment of good sections below the Berriedale Limestone has indicated a number of formations previously included as Snug Stage or ignored. These new formations are defined here and formal definitions suggested for those terms used earlier. When dealing with each formation whether new or old, apparent synonymys will be listed and the nomenclature discussed.

STRATIGRAPHY

In the detailed section on the eastern flanks of Mt. Nassau there are at least 15 formations and by considering sections elsewhere in the district at least two more can be recognised below the lowest one at Mt. Nassau. The type section will be discussed in detail and then short notes on other sections will provide comparisons with the type.

Bundella Mudstone

The Bundella Mudstone is that formation consisting dominantly of siltstone with subordinate sandstone bands which is exposed in road cuttings on the Lyell Highway between Parramore Creek and Geiss Creek and in the lower part of Geiss Creek. It is overlain by the Geiss Conglomerate and its base is hidden by alluvium. It is at least 140 feet thick and contains *Eurydesma cordatum, Keeneia platyschismoides, Stenopora johnstoni* and *S. tasmaniensis*. It is Permian and probably Lower Artinskian in age. The name is derived from Bundella Railway Station on the northern bank of the Derwent River, near which this formation was first recognised. The co-ordinates of the centre of the type area are 504·8 E-736·8 N.

Synonymy

Bundella Mudstone
Banks, Hale and Yaxley, 1955, pp. 219, 227.
Banks in Hill, 1955.

Porter Hill Beds
Johnston 1888, pp. 105 *et seq.*, very approximately only.

"Porters Hill" Siltstone
Banks, Hale and Yaxley, 1955.

Snug Stage
Lewis, 1946, p. 26 *et. seq.*, very approximately only, if at all.

Lithology

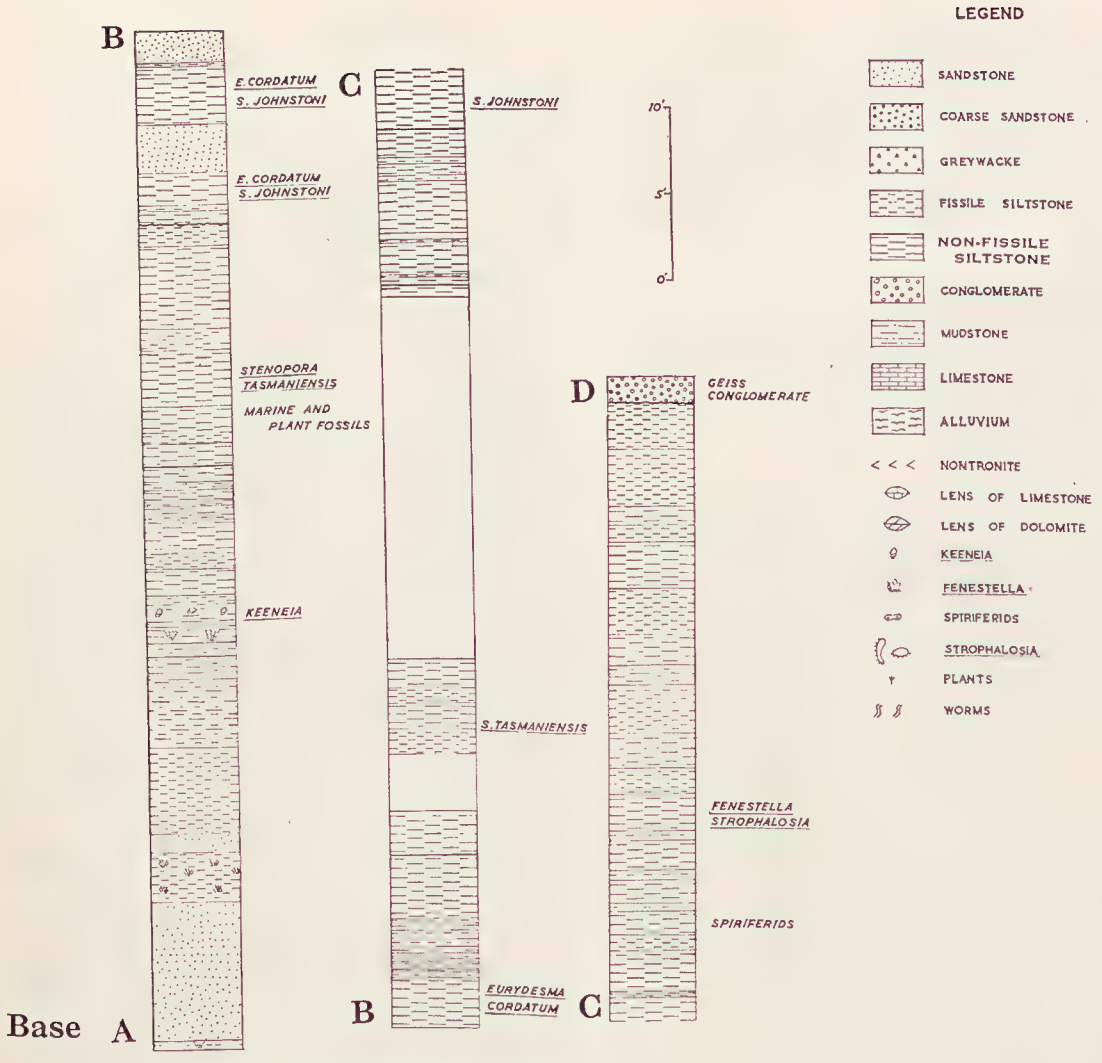
For the most part this formation is a regular alternation of fissile and non-fissile siltstone which in the lower parts of the formation as exposed in the type section is richly fossiliferous. Near the base there at at least four beds of sandstone which weathers into small, somewhat cuboidal blocks. Most of the beds contain erratics, one of which is an irregular block of quartzite three feet across but most of the erratics are less than eight inches in diameter. The erratics are frequently facetted and a few are also striated. There are many rock types represented by the erratics. The succession in the type section along the road cuttings and in the lower parts of Geiss Creek is shown in text figure 2.

Thin sections were cut of the representative rock types in the Bundella Mudstone. The non-fissile siltstone consists of 30-40 per cent of rock fragments which include quartzite, schist, phyllite and granite, 20-30 per cent of quartz some of which shows undulose extinction and some of which appears to have reacted with the matrix, 20 per cent of fine grained groundmass, 5-10 per cent of feldspar including orthoclase, microcline and plagioclase both fresh and altered to sericite, 5-10 per cent of mica mostly muscovite which appears to be squeezed around the other grains, and a few grains of zircon, apatite and tourmaline. The grains are dominantly in the silt grade but particles from clay grade to sand grade (1·5 mm.) are present. On the whole sorting is poor but there are a few finer bands. However, no mechanical analyses have been done. Particles of all grades are sub-angular to angular and equidimensional to bladed. There is no preferred orientation visible. The fissile siltstone is essentially the same as the non-fissile but shows better sorting, bedding is apparent and there is some orientation of the micas. In addition it is somewhat finer-grained, the dominant size in the sand grade being about 0·2 mm. whereas that in the non-fissile is 0·25-0·3 mm. Iron staining occurs in both types and in the fissile type is parallel to the finer beds but in the coarser beds is at an angle to the bedding.

The colour of the rock when weathered is buff but they tend to be yellowish-grey or light olive-grey when fresh.

A thin section of an unfossiliferous siltstone from the top of the Bundella Mudstone showed that it consists mainly of quartz and mica of coarse silt grade in a fine silt to clay grade matrix. The grains are dominantly angular and are equant to bladed. The micas show distinct parallel orientation which is reflected also by lines of haematite. In addition to quartz and muscovite the rock contains rare grains of plagioclase, some blue tourmaline, green biotite and some chlorite. Rock fragments include some of quartz muscovite schist and some of the quartz in the rock shows undulose extinction indicating possible derivation from a metamorphic source.

The sandstones are olive in colour. They consist of about 30 per cent of quartz, 5-10 per cent of feldspar, both orthoclase and plagioclase, 10-15 per cent of mica, mainly muscovite but with some biotite and 40-50 per cent of groundmass and rock fragments with minor amounts of zircon, apatite and garnet. The rock fragments are mainly of metamorphic rocks rich in mica. Many of the quartz grains have inclusions of garnet, apatite and zircon. Sorting is good with most of the grains in the sand grade (0·06 to 0·1 mm.). No bedding is apparent in the thin sections nor is there any apparent orientation of the micas, which are of



SECTION OF THE BUNDELLA MUDSTONE MT. NASSAU SECTION

FIG. 2

the same grain size as the other minerals in the sections. The grains are equidimensional to bladed and sub-rounded to sub-angular.

A thin section of a conglomeratic siltstone close to the top of the formation showed that the rock is composed dominantly of rock fragments, with up to 15 per cent of quartz, 5-10 per cent of muscovite, 5 per cent of feldspar, mainly plagioclase with some orthoclase, and 5-10 per cent of groundmass. Heavy minerals present include zircon, garnet and calcite. The quartz is usually bladed and the muscovite twisted around the other grains. Particles in the groundmass range in size from clay grade to near the top of the silt grade (0·04 mm.) although there were a few longer, very thin almost acicular fragments composed of a number of grains of quartz forming a mosaic. In some places these very long grains show a preferred orientation but in most parts there is no preference. Grains other than the acicular grains are bladed to equidimensional and angular to sub-rounded. A few flakes of green biotite are present in addition to the more abundant muscovite. The rock could probably best be described as a poorly sorted conglomeratic siltstone.

One of the most noticeable features of this formation in the field is the alternation of fissile and non-fissile beds. Near the base the non-fissile bands are consistently rather thicker than the fissile bed above them, but towards the top the position is reversed. It seems from preliminary examination that the fissility could be a function of the better sorting and the orientation of the micas.

Both of these differences suggest that current or wave action was stronger during the deposition of the fissile beds than during the formation of the non-fissile beds. The alternation in the intensity of current and wave action could be a function of changes in sea-level, involving changes in depth and/or distance from shore, or of climate affecting the velocity and volume of water entering the sea in rivers, or of climate affecting the intensity of glaciation and altering the mode of transport and distance of transport of the sediment, or of several of these factors and perhaps others operating together. Tectonic activity in the source or depositional area could also cause changes in the intensity of current action but it is difficult, but by no means impossible, to account for the remarkably regular alternation on such a small scale under a tectonic hypothesis. As far as can be judged on information at present available the beds are of almost constant thickness over distances of half a mile along the dip and a quarter of a mile along the strike. They show no or very little cross-bedding which is in accord with the general lack of sorting but they also show no obvious graded bedding. Contacts between adjacent beds are normally gradational. Thus there is little if any evidence of the action of turbidity currents and slump structures were not seen either in the field or in thin section. From the information available in this one section it would seem unwise to choose one cause rather than another for the alternation but as regional work is done and three dimensional evidence becomes available the cause should be revealed.

The sandstone beds apparently represent even better conditions of sorting than either of the siltstones and it is noteworthy that they seem to lack erratics. They possibly represent times of fall in sea-level producing shallowing of the water and increase in current action and at the same time a reduction in the density of icebergs in the vicinity relative to other times or else the current action is strong enough to separate the sand from the coarser grades, e.g., erratics.

Palaeontology

Fossils are abundant in both the fissile and non-fissile beds but seem to be rare in the sandstone. The fissility is not controlled by abundance and type of fossils except near the base where fenestellid fronds parallel the bedding and increase fissility. Many phyla are represented but braciopods and bryozoa are the most abundant. The brachiopods are predominantly spiriferids but some *Strophalosia* spp. are also present. Significant bryozoa are *Stenopora johnstoni* and *S. tasmaniensis* which are commonest in, if not restricted to the lower part of the Permian sequence of Tasmania. Fenestellids including *Fenestella* spp., *Polypora* spp. and *Protoretepora* are common. The pelecypod *Eurydesma cordatum* is present on several horizons and other pelecypods are present but not common. Gasteropods are also common, the main forms being species of *Mourlonia* but *Platyschisma ocula* and a *Straparollus* are also present. An important gasteropod which occurs in the lower part of the formation is *Keeneia platyschismoides* which is significant for correlation. Ostracodes are present and abundant on some horizons. Near the top of the formation fossils become very rare and the rock could easily be mistaken for the Ferntree Mudstone, a feature noted by Lewis (1946, p. 30).

Correlation

The abundance of *Stenopora johnstoni, S. tasmaniensis* with the presence of *Eurydesma cordatum* and *Keeneia platyschismoides* as well as the lithology suggests that the Bundella Mudstone is equivalent to the beds along the foreshore at Sandy Bay just above the blue-grey limestone with *Calcitornella* which has been correlated by Banks (1957 *b*) with the Darlington Limestone. These beds are what Johnston referred to in 1888 as the Porter Hill Beds but beds referred to by this name seem to go higher into the sequence than the Bundella Mudstone and the name has been used by later workers for the beds in the top of Johnston's (1888) Porter Hill Beds which are almost certainly not equivalent to the Bundella Mudstone. The Bundella Mudstone was first recognised on the northern side of the Derwent River on the slopes of Mt. Dromedary above Bundella Station. Recently in this area I. McDougall discovered a richly fossiliferous limestone, in which *Eurydesma cordatum* was a prominent fossil on some horizons, just below the Bundella Mudstone. This is correlated with the Darlington Limestone and on the flanks of Mt. Dromedary occurs about 140 feet below the base of the Faulkner Group so that it might be expected to occur just below the lowest outcrop in the Mt. Nassau section. In the Collinsvale and Glen Lusk Road sections a *Eurydesma*-rich limestone with *Calcitornella* is overlain by richly fossiliferous mudstones which would therefore be equivalent to the Bundella Mudstone. At Snug the section is not clear but the base of it exposed in cuttings on the Channel Highway just north of the bridge over the Snug Falls River is an alternation of fissile and non-fissile siltstone with some limestone bands and the siltstones are very rich in *Eurydesma cordatum*. These are probably correlates of the Bundella Mudstone but more detailed stratigraphic work is necessary to establish this. They underlie a fossiliferous erratic-rich conglomerate which is probably the equivalent of the Geiss Conglomerate and this is succeeded by the mottled-brown mudstone and sandstone of the Snug Stage of Lewis (1946) in its type area. It will be shown later that on present stratigraphic knowledge the best correlation of the Snug Stage is with the Faulkner Group. In the Collinsvale Road section the Darlington Limestone is underlain by a considerable thickness of dark-grey pyritic siltstone which is probably equivalent in a general way to the beds below the Darlington Limestone on Woody Island, especially the Woody Island Siltstone. It appears then that these beds in the lower part of the section on the Collinsvale Road are the lowest exposed in the Hobart area although the section below the Huon Road section should be investigated in this connection. On Woody Island the Darlington Limestone is overlain by about 40 are the lowest exposed in the Hobart area. On Woody Island the Darlington Limestone is overlain by about 40 feet of richly fossiliferous alternating fissile and non-fissile siltstone which contains,

among other fossils, *Keeneia platyschismoides*. These beds are correlated on lithological and palaeontological grounds with the Bundella Mudstone (Banks, Hale and Yaxley, 1955). On the northern end of Maria Island the Darlington Limestone is much thicker than in the Hobart area and may be partially equivalent in time to the Bundella Mudstone. It is overlain by sandstones and siltstones which could also be equivalent to the Bundella Mudstone but they are lithologically rather different. The Bundella Mudstone would appear on stratigraphic evidence to be equivalent to the richly fossiliferous siltstones above the Darlington Limestone in the Deloraine area, i.e., to the top part of the Golden Valley Limestone and Shale of Wells (1957).

The presence of *Stenopora johnstoni, S. tasmaniensis, Eurydesma cordatum* and *Keeneia platyschismoides* suggests correlation with part of the Dalwood Group of New South Wales. The fact that it overlies a limestone with *Calcitornella* suggests correlation with part of the Rutherford Formation (in New South Wales) which includes and overlies a foraminiferal limestone with the same fossils.

Conditions of Deposition

The Bundella Mudstone is a marine formation for the most part and even in the top part of the formation where fossils are rare it is still marine although the relative absence of fossils suggests that the conditions of life deteriorated during the latter part of the time during which the Bundella Mudstone was being deposited. Possibly the water became brackish at this time although there are other possibilities. The fossils, especially the pelecypods gasteropods, spiriferids and *Stenopora johnstoni* all suggest shallow water deposition, but currents and waves apparently did not affect the bottom very greatly. Judging from the erratics in the siltstone icebergs were common in the sea in which the Bundella Mudstone was being deposited. Alternations in the intensity of current and wave action occurred. The land surface supplying the sediment included schists and quartzites of several types and some granite masses. The metamorphic rocks correspond best to the Precambrian rocks of Tasmania but no diagnostic types have been noticed.

Faulkner Group

The Faulkner Group is here defined as all those formations lying between the Bundella Mudstone below and the Rayner Sandstone above and consists in this, the type area, of seven formations as listed below from the base upwards: Geiss Conglomerate, Rathbones Sandstone and Siltstone, Byers Sandstone, Jarvis Siltstone, Parramore Sandstone and Shale, Altamont Conglomerate and Fergusson Siltstone. The type area for all of these formations is along Geiss Creek.

The rocks in the succession in Geiss Creek pose a problem in stratigraphical nomenclature. Some of the formations listed above are very thin and can only be traced for short distances on the ground away from the creek and some have been recognised with certainty only in the creek bed itself. Several of them are not strictly formations in the sense that they are mappable units, because they are not mappable except on a very large scale. Each formation is however, composed of a single rock type or alternation of rock types. The group on the other hand is composed of a variety of rock types but is the mapping unit for work on air photo scale (20 chains to the inch). To regard the group as a formation and each individual formation as a member is perhaps the obvious thing to do but it ignores the diversity of rock types, subgreywacke conglomerates, subgreywackes siltstone, siliceous sandstones and siliceous siltstones and makes it impossible to express this diversity adequately without considerable circumlocution. It is impossible to find a lithological term to adequately describe the rocks in such a formation. Although several of the formations are only 18 inches thick, and are not mappable units in the usual sense of the words and thus perhaps do not warrant separate status, similar rocks occur in similar stratigraphic positions in other parts of the State and to express correlations concisely it is necessary to name them. Finally all the formations in this group are parts of two cyclothems and are thus genetically connected so that the term group is permissible for such a collection in the terms of the recent definition of the word in the revised code of stratigraphic nomenclature for Australia (Raggatt, 1956).

Geiss Conglomerate

The Geiss Conglomerate is that formation of subgreywacke conglomerate 18 inches thick which occurs in the lower part of Geiss Creek (co-ordinates 504·7 E-736·6 N) and on the hill slopes to the east. It is underlain by the Bundella Mudstone and overlain by the Rathbones Sandstone and Siltstone. It is Permian, probably lower Artinskian, in age.

Although this formation is so thin it can be traced for about half a mile around the hill slope between Geiss Creek and Parramore Creek and can be identified again in Rayner Creek, it has an uneven base on the underlying fissile siltstone of the Bundella Mudstone where the contact is exposed in Geiss Creek. It is olive-brown in colour (5 Y 5/4) and in the field is apparently a poorly-sorted conglomerate containing angular to rounded rock fragments up to cobble size in a groundmass of angular to sub-rounded grains of quartz, feldspar and mica. It has no internal bedding planes and is not fissile. The rock fragments which in Geiss Creek are up to three inches in longest dimension and in Rayner Creek are up to eight inches long, are of quartz, quartzite, granite, schist, phyllite, slate and feldspar porphyry and are commonly facetted. In the Rayner Creek occurrence the top of the bed contains plant stems and a few *Gangamopteris* leaves.

A thin section showed that the rock consists of rock fragments at least up to pebble size in a very poorly sorted groundmass of sand, silt and clay grade. Mineral fragments include much quartz, both fresh and weathered microcline, plagioclase, muscovite and a little biotite. The groundmass is composed of quartz, muscovite, much chlorite and carbonaceous material. The mineral fragments in all grades were angular to almost cuspate. The rock fragments include sheared quartzite, micaceous quartzite, muscovite schist, and muscovite

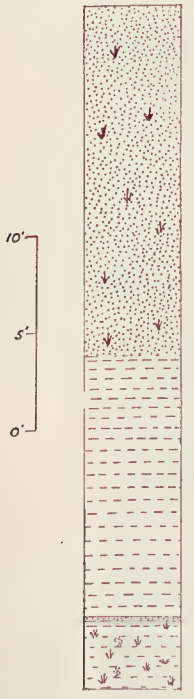
chlorite schist. Other rock fragments are now mainly ferruginous material. There is no bedding or any other type of orientation of the fragments. The rock is a sub-greywacke conglomerate.

The Geiss Conglomerate was apparently deposited in an environment of little or no current or wave action and under conditions of little water or wind transport from its source. The only fossils known in it are plants so that the *a priori* assumption is that it was deposited on land but a marine origin under conditions where marine life was inhibited is not impossible. Until more is known of its areal distribution and variations in thickness and lithology it is premature to assign it to any specific environment.

Rathbones Sandstone and Siltstone

The Rathbones Sandstone and Siltstone is that formation of quartz rich sandstone and fissile siltstone overlying the Geiss Conglomerate and underlying the Byers Sandstone in the bed of Geiss Creek. It is 35 feet thick. Fossils include worm casts and plant fragments. It is Permian, probably Lower Artinskian, in age. It is named for Rathbones Lime Kilns on the eastern side of Rayner Creek (505·8 E-737·3 N) in the bed of which the formation was first recognized.

In Geiss Creek this formation consists of four units, the succession being illustrated as text figure 3.



SECTION OF RATHBONES SILTSTONE AND SANDSTONE MT NASSAU SECTION

FIG. 3

(for legend see fig. 2)

The basal unit is a well-sorted, light olive-grey carbonaceous siltstone with thin bedding and containing some worm casts. It is followed by a yellowish-grey quartz sandstone with feldspar visible in hand specimen. The next unit is a dark-grey, very thinly bedded fissile siltstone which is noticeably micaceous and contains lenses of cross-bedded sandstone. The final unit is a yellowish-grey, pale-red or medium-grey sandstone composed dominantly of quartz but with quite a lot of feldspar and golden mica. It is essentially an alternation of thin-bedded fissile beds and thick-bedded non-fissile beds. Sets of cross bedding up to three feet thick were noticed in the field and ripple marks and mud pellets are common.

A thin section of the fissile, thin-bedded siltstone shows that it contains quartz, both muscovite and biotite, and some rock fragments in a groundmass of clay, chloritic material and mica. The content of feldspar is very low. Zircon and tourmaline are present in minor quantities. The grains are not even in grain size and are angular except for the zircon in the finer bands which is rounded. Cross bedding is visible in the thin section.

A sandstone from the top unit was sectioned and the section showed that it is composed mostly of quartz (70%) and mica (25%) with the rest made up of zircon, tourmaline and garnet grains with some opaque iron minerals. There is very little groundmass and very few rock fragments most of them quarzitic. No feldspar is visible. Both muscovite and biotite are present with the former more abundant than the latter. It is well-sorted with the grain size about ·05-·1 mm. The grains are equidimensional and with the exception of the zircon lack rounding and are remarkably angular. There is some suturing of the quartz grains producing a mosaic texture. The micas are well oriented.

The overall lithology of this formation is very reminiscent of that of the lower part of the Triassic of Tasmania, i.e., the Knocklofty Sandstone and Shale and when first found in the lower part of Rayner Creek the question of a fault dropping the Triassic into the Permian sequence was seriously entertained but the exposures in both creek beds are such that there is no doubt of the Permian age of the formation. The similarity of this formation to the Triassic is heightened in the vicinity of Rayner Creek by the occurrence of slump structures in the sandstone and the occurrence of graphite flakes on the bedding planes. Current ripples with currents coming from a generally southerly direction are present in a cliff section on the western side of Rayner Creek.

The only fossils found were some plant fragments and the worm casts in the basal unit in the Geiss Creek section.

This formation is very different from the underlying formations in several important respects. Rock fragments are much less common, sorting is very much better and cross bedding, ripple marking and slump structures occur. Mica is much more abundant and better oriented than in the silt-

stones of the Bundella Mudstone. Also significant is the occurrence of pellets of mudstone in the higher sandstones. Apparently current action was much stronger during the deposition of this formation than the earlier ones and icebergs not present in the depositional area. The mud pellets suggest very shallow water and the plant fossils and carbonaceous material suggest a terrestrial origin although the worm casts are more difficult to interpret. Similar types of worm casts are present in the Ferntree Mudstone which is generally considered to be marine, or at least estuarine. However, the occurrences of worm casts elsewhere in the Permian in Tasmania need further study before their significance is finally appreciated. It is possible that the lower part of the formation is marine and the upper part lacustrine or paludine in origin. The angularity of almost all the grains in the rocks of this formation is somewhat anomalous but is consistent with brief reworking of earlier Permian rocks with the sorting of the various grades by streams or in lakes or swamps and short transport to the depositional site. The mica could well also have been concentrated from earlier Permian sediments in the same way as the quartz while the feldspars from the older sediments were either physically or chemically removed. The presence of such a high proportion of heavy minerals in the top unit also supports some reworking hypothesis. Variations in competence of the transporting medium are reflected in the presence of both siltstone and sandstone.

This formation has not been recognized with any certainty anywhere else in the Hobart area but similar beds occur in the same relationship to beds correlated with the Bundella Mudstone on Maria Island and in the Cressy-Deloraine area where they form part of the Liffey Sandstone of Wells (1957). No direct palaeontological evidence for this correlation is available.

Byers Sandstone

The Byers Sandstone is that formation of sub-greywacke sandstone exposed in Geiss Creek between the Rathbones Sandstone and Siltstone below and the Jarvis Siltstone above. It is only two inches thick. It is Permian, probably Lower Artinskian, in age. It is named after Byers Creek, whch has the co-ordinates 506·3 E-737·5 N.

In the field this rock appears to be a poorly sorted, medium to coarse-grained sandstone with pebbles of porphyry, quartz and quartzite in a groundmass of angular to sub-angular grains of quartz, feldspar and mica. It is dusky yellow in colour. A thin section revealed that it contains 40 per cent of quartz, 30 per cent of rock fragments, 15 per cent of mica, 10 per cent feldspar and 5 per cent of groundmass with minor quantities of zircon, tourmaline, apatite, garnet and epidote. The groundmass is chloritic and micaceous with some haematitic cement. The feldspar includes plagioclase and both muscovite and green biotite are present.

Examination of the thin section reveals that the rock is better sorted than it appears to be in the field. Many grains from 0·125-0·25 mm. in size occur in a groundmass of fine silt to clay grade. The grains and the groundmass are in about equal proportion. The grains are angular, even cuspate, to sub-angular and equidimensional to somewhat bladed. There is distinct parallelism of the bladed grains in some parts of the section but in others their orientation is apparently random. Some of the mica flakes have been moulded around the other grains in a complex fashion.

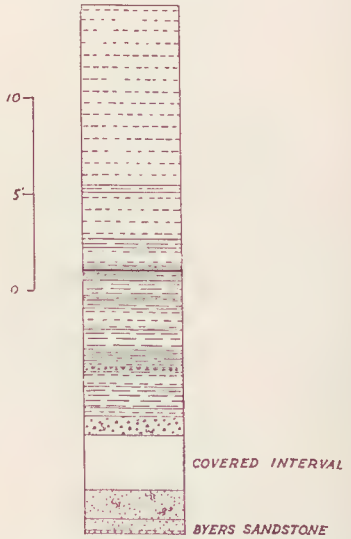
No fossils were seen in thin section or in the field.

The rock could best be described as a very fine sub-greywacke sandstone, with fair sorting only.

Jarvis Siltstone

The Jarvis Siltstone is that formation of siltstone exposed in Geiss Creek between the Byers Sandstone below and the Parramore Sandstone and Siltstone above. It is approximately 27 feet thick. It is Permian, probably Lower Artinskian, in age. It is named after Jarvis Creek, the mouth of which has the co-ordinates 504·0 E-736·3 N.

This formation consists in the creek exposure essentially of an alternation of fissile and non-fissile sub-greywacke siltstones which resemble the upper part of the Bundella Mudstone very much. This alternation is shown in the section (text figure 4) from which it will be seen that the two lower units are rather coarser-grained and in the field are a little better sorted than units higher in the formation.



SECTION OF JARVIS SILTSTONE

MT NASSAU SECTION

FIG. 4

(for legend see fig. 2)

Erratics are absent in the lowest unit but in higher beds are always present and in one or two cases common. The first three units are non-fissile

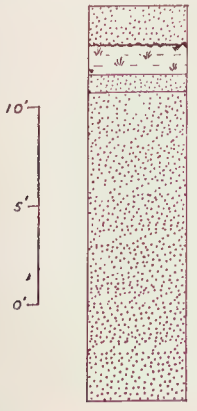
but higher beds show the alternation mentioned above, the fissile beds being usually slightly thicker than the non-fissile. The lowest unit is dusky-yellow, the next one light olive-grey and in the higher beds there is an alternation of mottled (olive-grey and dark-grey) and dark-grey beds, the mottled beds being the non-fissile, slightly coarser beds. Lithologically this unit is very like the Ferntree Mudstone higher in the sequence. Fossils are very uncommon and were observed only in the second and third units where only worm tubes were seen. The fissile units in the formation become progressively thicker upwards.

Examination of thin sections showed that the rock is composed of granules of quartz, quartzite and biotite in a matrix of very fine sand and coarse silt. The rock is poorly sorted but one slide showed signs of very rude bedding and even slump structure. In the other slide it is noticeable that the larger grains are clumped together. The grains are angular to cuspate except for some of the granules which show signs of rounding. The rock fragments include quartzite, micaceous quartzite, quartz muscovite and quartz biotite schist. The dominant mineral is quartz but plagioclase, muscovite, brown biotite and haematite are also present. The rock is a sub-greywacke siltstone.

Parramore Sandstone and Siltstone

The Parramore Sandstone and Siltstone is that formation of quartz sandstone and carbonaceous siltstone which outcrops in Geiss Creek between the underlying Jarvis Siltstone and the overlying Altamont Conglomerate. It is 20 feet thick. It is Permian, probably Lower Artinskian, in age. It is named after Parramore Creek, the mouth of which has the co-ordinates 505·2 E-736·8 N. It contains only plant fragments.

In the creek outcrop of this formation, of which text figure 5 is a columnar section, the basal unit is a micaceous quartz sandstone which appears to be very fine grained and well sorted.



SECTION OF PARRAMORE SANDSTONE AND SILTSTONE
MT. NASSAU SECTION
FIG. 5
(for legend see fig. 2)

It is a very pale greenish-yellow colour. Within the unit are five sets, each about eight inches thick, of fine-grained cross-bedded sandstone. The only fossils found to date are a few carbonaceous fragments. There are no erratics. The next unit is a fine-grained, cross-bedded sandstone and this is followed by a thinly bedded carbonaceous siltstone which contains lenses of cross-bedded or slumped sandsone. It is dark-grey in colour. The top surface of this unit is quite uneven suggesting some disconformity. The next unit is a thick to thinly bedded quartz sandstone with some feldspar and mica visible in the field and also a few pebbles of quartz and quartzite. Cross-bedding sets of up to two feet thick are present but the thickness of the sets varies considerably.

Thin sections were cut and examination of these showed that the siltstone consists almost entirely of quartz and muscovite with a few grains of biotite, both brown and green, plagioclase and tourmaline. Haematite is common. It is a very well sorted medium-grained siltstone.

This formation is similar in lithology to the Rathbones Sandstone and Siltstone. Again well sorted quartz rich sandstones are associated with quartz-rich carbonaceous siltstones. Cross-bedding and slumping are present in the sandstones in both and both contain plant fragments. The association of characters suggests similar conditions of formation to those applying during deposition of the Rathbones Formation and in this case there is a suggestion in the uneven surface of the second last unit and the basal fine-grained conglomerate of the top unit of penecontemporaneous erosion, producing a sort of scour and fill structure.

Altamont Conglomerate

The Altamont Conglomerate is that formation of sub-greywacke conglomerate overlying the Parramore Sandstone and Siltstone and underlying the Fergusson Siltstone in Geiss Creek. It is 18 inches thick. It is Permian, probably Lower Artinskian, in age. It is named after the township reserve of Altamont about a mile to the west of Geiss Creek. The co-ordinates of the type section are 504·7 E-736·6 N.

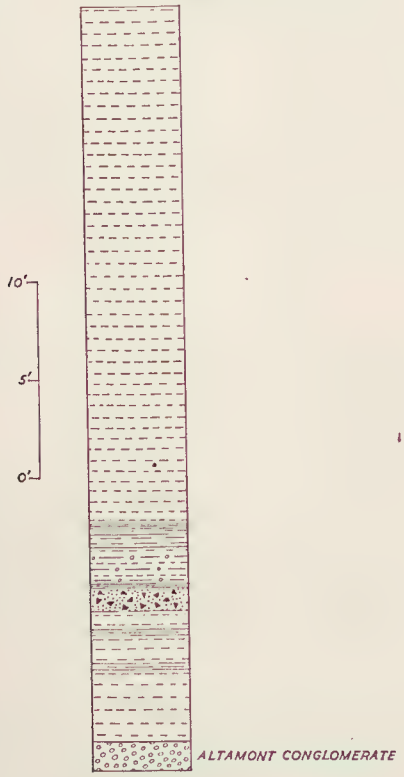
This formation consists of a single bed of light olive-grey conglomerate composed of pebbles of quartz, quartzite and mudstone in poorly-sorted matrix of sand grade composed of angular to sub-angular grains of quartz, feldspar and mica. The pebbles are sub-angular to rounded. The rock also contains pellets of mudstone which are angular and suggest shallow water conditions with some penecontemporaneous scour.

Fergusson Siltstone

The Fergusson Siltstone is that formation of siltstone with minor conglomeratic bands which occurs in Geiss Creek between the Altamont Conglomerate below and the Rayner Sandstone above. It is 37 feet thick. It is Permian, probably Artinskian, in age. It is named after Fergusson Creek which is a tributary of Jarvis Creek to the west of Geiss Creek. The co-ordinates of the type area are 504·7 E-736·6 N.

This formation is essentially an alternation of fissile and non-fissile siltstone in which two of the non-fissile units are markedly conglomeratic. The

lowest unit is a medium to dark-grey fissile siltstone containing some sub-rounded quartz pebbles in a fairly well-sorted groundmass of quartz, feldspar and abundant mica. This is succeeded by a fissile siltstone which appears to be otherwise like the first unit, then another similar alternation. The next alternation commences normally with a fissile siltstone but the other member is a very tough, thick-bedded, conglomeratic unit. It contains numerous erratics up to eight inches in diameter in a poorly-sorted groundmass of angular to sub-angular grains of quartz and feldspar. It is dark-grey to medium dark-grey. It might best be called a greywacke breccia and is very like the rock which Montgomery (1891) called a "tuff" on Maria Island. The next cycle is also abnormal although it again commences normally with a fissile siltstone. The top member is again a conglomeratic bed with erratics up to three and a half inches in diameter distributed through it. It is dominantly fissile but there are thin non-fissile bands in it. This is succeeded by a brittle, dark-grey siltstone after which is one normal cycle before the formation ends with a fissile siltstone in which there are rare marine fossils near the top. This succession is summarised in columnar form as text figure 6. The



SECTION OF FERGUSSON SILTSTONE
MT NASSAU SECTION

FIG. 6
(for legend see fig. 2)

formation thus consists of five complete alternations and the lower half of another. With the exception of the cycle involving the greywacke breccia all cycles have a thicker fissile than non-fissile component. In this respect the cycles are like those high in the Bundella Mudstone.

Lithologically the rocks in this formation are very like those in the Jarvis Siltstone and the top of the Bundella Mudstone and also like the Ferntree Mudstone. In the Fergusson Siltstone the presence of marine fossils in the upper part of the formation indicates that it at least is partly marine. As the lower beds in the formation are very similar to these higher fossiliferous ones except for the fossils it is probable that they were formed under similar conditions except for some factor, perhaps relative freshness of water.

Near the base of the formation is a well-sorted bed called a siltstone in the field. This was sectioned and seen to be composed of quartz, fresh and weathered plagioclase, muscovite, brown biotite, blue tourmaline, microcline, zircon and magnetite and fragments of quartz muscovite schist and biotite schist. The grains are mainly of sand size but there are a few granules and some silt. The rock is somewhat sorted, as there is only a minor amount in the silt grade. The sand grains are frequently in contact and have developed a mosaic texture in several places. The grains are mainly equant but a few are bladed. No bedding is apparent in the slide.

A fissile siltstone from higher in the formation contains a few grains of sand grade in a matrix which is dominantly fine to medium-grained silt. The grains are angular. There is a rude parallelism of the carbonaceous patches in the slide and the muscovite flakes. The main minerals present are quartz and muscovite but there is also much carbonaceous matter and haematite.

The greywacke breccia is very poorly sorted and consists of pebbles, granules and sand grade fragments in a groundmass which forms 20 per cent of the rock. The granules include large pieces of quartz, plagioclase, and brown biotite as well as quartzites. Magnetite is common. The grains are mainly angular to cuspate but a few are sub-rounded. The groundmass is mainly quartz but there is much other material present.

Cyclic Deposition in the Faulkner Group

It has been noted that the Faulkner Group consists of two distinctly different associations of lithological types, conglomerates, sandstones and siltstones of the sub-greywacke suite and sandstones and siltstone of the orthoquartzite (quartz sandstone suite). What is perhaps more interesting is that the rocks of these two suites occur in regular alternation and still further form parts of two cyclothems as will be seen from the following summary:

Top:

Sub-greywacke siltstone (Fergusson Siltstone)
Sub-greywacke conglomerate (Altamont Conglomerate)
Quartz sandstone and carbonaceous quartz siltstone (Parramore Formation)

Sub-greywacke siltstone (Jarvis Siltstone)
Sub-greywacke sandstone with erratics (Byers Sandstone)
Quartz sandstone and quartz siltstone (Rathbones Formation)
Sub-greywacke siltstone with erratics (Geiss Conglomerate)
Sub-greywacke siltstone (Bundella Mudstone)

It is further noteworthy that the base of the Bundella Mudstone and the top of the Fergusson Siltstone are fossiliferous while the top of the Bundella Mudstone and the base of the Fergusson Siltstone are unfossiliferous. Thus the Faulkner Group consists of two cyclothems beginning with a sub-greywacke siltstone, passing through a thin sub-greywacke conglomerate into quartz-rich sediments back into sub-greywacke sandstone with erratics and finally back into sub-greywacke siltstone when the whole cycle commences afresh, the second cycle however lacking the second unit in the cycle, the conglomeratic one, but showing the higher conglomerate, the fourth unit.

The fossiliferous nature of the two ends of the double cyclothem suggest that they began and ended under marine conditions, normal except for the presence of floating ice. The presence of the reworked quartz-rich rocks on two horizons with plant remains suggests two emergences so that the cyclothems could be interpreted as due to two emergences separated by a short submergence. Thus the fossiliferous marine sub-greywacke siltstones represent normal marine conditions in this area followed by rather shallower, perhaps brackish estuarine conditions, unfossiliferous sub-greywacke siltstone, then shoreline conditions, the conglomerates, and finally lacustrine and paludine conditions on a flat coastal plain with reworking of the underlying marine sediments (quartz sandstone and carbonaceous siltstone). Then the sea began coming in over the coastal plain till the Mt. Nassau area was again covered by a shallow, perhaps brackish sea. After a short period emergence began again and the second cycle commenced, ending with the return to normal marine conditions.

This interpretation requires that the sub-greywacke conglomerates should be shoreline deposits formed by advancing and retreating seas. Such deposits could be formed where the rate of advance and retreat was fairly rapid, so that time for sorting was short, and where the supply of detrital material was greater than the amount able to be winnowed by the sea before emergence or burial under later marine sediment.

This interpretation of the cyclothems seems to meet all the facts known in this restricted area but requires confirmation from detailed work in other areas. Of particular interest is the distribution of the conglomeratic members of the cyclothems and any variations in thickness and lithology that they show.

The Faulkner Group is possibly partly equivalent to the Porter Hill Beds of Johnston (1886) who used this term originally for shales with *Cythere* and *Gangamopteris*. The usage of the unit called "Porter Hill" has varied from one author to another and even Johnston (1888) included more beds in it than he had originally so that his second meaning became all the beds between the limestone on the shoreline at Sandy Bay and the Grange Mudstone. This unit is thought to be equivalent to the Bundella Mudstone, the Faulkner Group and the Rayner Sandstone of the Mt. Nassau section. Voisey's (1938) Porter's Hill Stage is the same as that of Johnston (1888) and this usage was followed also by Lewis (1946, Porter's Hill Beds) and David (1950, Porters Hill Stage). Banks (1952) used the term for those beds in the road cutting at Porter Hill which contain plants at road level and are probably equivalent to the Altamont Conglomerate and Fergusson Siltstone. Finally Banks, Hale and Yaxley (1955) used the term "Porters Hill" Siltstone for the siltstones and sandstones just above the limestone at Sandy Bay which are thought to be equivalent to the Bundella Mudstone. It will be seen that there are several interpretations of this unit and that the spelling has varied also. We are advised that Porter Hill or Porter's Hill is not a name recognized by the Topographic Nomenclature Board but that either name would be suitable as a Mr. Porter owned land in this vicinity during the last century. We propose to suggest to the Board that the spur on which the section is found should be called Porter Hill to revert to Johnston's original spelling. The exact position of the Porter Hill Beds in the sequence must await detailed stratigraphic work on the type section. This group is also partly equivalent to the Preolenna Coal Measures of Hills and Carey (1949) and Fairbridge (1953).

The Faulkner Group, representing emergence, can be correlated on this ground with the Liffey Sandstone of Wells (1957) and this has been correlated by Banks (1957*a*) with the Mersey, Preolenna and Mt. Pelion Coal Measures. This terrestrial interlude in the marine sequence corresponds approximately to the Greta Coal Measures of New South Wales but exact equivalence is not suggested. Detailed correlations both within and outside Tasmania must await more detailed stratigraphical and palaeontological work.

Rayner Sandstone

The Rayner Sandstone is that formation of sandstone outcropping on the hill slope west of Geiss Creek and overlying the Fergusson Siltstone and underlying the Cascades Group. It is about nine feet thick. It contains marine fossils and is Permian, probably Artinskian in age. It is named after Rayner Creek. The co-ordinates of the type area are 504·7 E-736·6 N.

This is the Bridgewater Sandstone of Banks in Hill (1955) which was established on the imperfect sections available in the Rayner Creek section and as formerly used included the Fergusson Siltstone. However, the name "Bridgewater" is not available as a stratigraphic name having been used by Lewis (1946) for the basalts near Bridgewater and earlier as the name of a phase in Pleistocene history of Tasmania. The better sections in and around Geiss Creek allowed this formation to be more correctly restricted.

The Rayner Sandstone is widespread in the Hobart area. It was first recognized on the hill slopes to the east of Rayner Creek, then on the

slopes of Mt. Dromedary where it has since been mapped over several miles by I. McDougall. The Rayner Sandstone is also recognizable beneath the Cascades Group on the Berriedale-Collinsvale Road just below the limestone quarries. Brill (1956, p. 140) records a sandstone below his Berriedale Limestone section at Weily's Quarry, Glenorchy, and a sandstone occurs in road cuts on Porter Hill at the base of the Cascade Group. Finally a greywacke sandstone occurs in this same stratigraphic position on Maria Island.

In the Geiss Creek section the basal unit of the Rayner Sandstone is an olive-grey to light olive-grey, thick bedded, poorly sorted, medium grained sub-greywacke sandstone, with erratics in a groundmass of angular to sub-angular quartz and feldspar. Fossils are present, though rare and include plants and marine fossils, especially *Martiniopsis*. The next unit is similar but more friable and the next unit again is like the first. The top unit is similar to the first but fossils are common and are predominantly marine.

Examination of thin sections of this rock showed that except for the relative scarcity of rock fragments it is like the greywacke breccia in the Fergusson Siltstone. The dominant grade is sand with particles of quartz, plagioclase, muscovite, biotite and zircon up to 1 mm. in length. Most of the grains are bladed but some are equant, most of them are angular but a few are sub-rounded. Schists are present as rock fragments. The groundmass forms 20 per cent of the rock. It is a sub-greywacke sandstone.

In the section up Rayner Creek the Geiss Conglomerate is succeeded by the Rathbones Formation but then the section is covered and the next unit recognized is exposed in the road to the western quarry. It is lithologically very like the greywacke breccia in the Jarvis Siltstone which has been likened earlier to the "tuff" on Maria Island. It contains *Glossopteris* and other plant fragments. It is approximately the same distance below the Rayner Sandstone as the bed in Geiss Creek. The Rayner Sandstone outcrops on the access road to the eastern quarry, and in this locality is a coarse feldspathic sandstone with small erratics near the base and larger ones towards the top. The boulders are angular and frequently facetted. Fossils occur abundantly in patches and include bryozoa, *Strophalosia* spp., *Martiniopsis*, *Platyschisma* and *Mourlonia*, as well as ostracodes.

Cascades Group

The Cascades Group is here defined as consisting of all those formations between the Rayner Sandstone below and the "Woodbridge Glacial Formation" above, that is of the Nassau Siltstone, the Berriedale Limestone and the Grange Mudstone in that order from the base upwards. The name is derived from the Cascades district about two miles west of Hobart. The type area of the group is, however, on the eastern flank of Mt. Nassau where all three formations are exposed in succession. The co-ordinates of the type area are 506·3 E-736·8 N.

Lewis (1946, pp. 22, 25, 30, 90) was the first to use this term or its equivalent (Cascades Stage) for the rocks included in this group. Later Hills and Carey (1949, pp. 31-2) used the term "Cascades Formation" to include the Granton Limestone and Marl, Porters Hill Mudstone and the Grange Mudstones and in effect applied it to all formations between the Wynyard Tillite and "Woodbridge Glacial Formation" which is a much wider usage than that proposed here. Fairbridge (1953) used the term Cascades Group for the Cascades Formation of Hills and Carey (1949). Prider used the term "Marlborough Series" in 1948 for the beds under the Woodbridge Glacial Formation at Marlborough and included the Bronte, Granton and Grange Facies. The Cascades and Marlborough Groups overlap to some extent, but the exact situation is not yet known. The formations of this group have been referred to as the Lower Marine Beds by Stephens (1885, pp. 218-219) and Johnston (1888), and as the Lower Marine Series by Lewis (1927, pp. 3, 9, 10), Nye and Lewis (1928, p. 34) Nye and Blake (1938, pp. 43, 44, 100) and David (1950). Present correlations on the other hand, see Banks (1957*a*), suggest rather that the Cascades Group is equivalent to part of the former Upper Marine Series of New South Wales, now the Maitland Group. In fact, even in Tasmania, detailed stratigraphic work has indicated that there are two major sequences of marine sediments separated by a fresh-water sequence, and of these the Cascades Group is part of the higher marine sequence. The unfortunate confusion resulting from the old naming has been dealt with earlier.

The total thickness of the Cascades Group is normally of the order of 300 feet but the thicknesses of the constituent formations vary considerably. In places, e.g., Coles Bay, Seymour, the group consists dominantly of the Berriedale Limestone with some Grange Mudstone. On Maria Island there is an appreciable thickness of Nassau Siltstone and rather a greater thickness of the Berriedale Limestone than of the Grange Mudstone. At Mt. Nassau the Nassau Siltstone is thin and the Berriedale Limestone thicker than the Grange Mudstone while at the type area of the Grange Mudstone, at Porter Hill, Sandy Bay, there is no Nassau Siltstone known, the Berriedale Limestone is thin and the Grange Mudstone is the predominant formation. Further south neither the Berriedale Limestone nor the Nassau Siltstone can be positively identified and the group consisted of a single formation, the Grange Mudstone.

The group is known from as far north as Avoca and Bothwell to as far south as Mt. La Perouse and from Marlborough in the west to the east coast. The apparent absence of this group from the Cressy and Deloraine areas and probably all parts of the north-west coastal area is an interesting problem.

The variations within the Group are attributed to facies changes as will be developed later. As a summary it might be said that the group consists of an alternation of fissile siltstones with limestones or calcareous siltstone, the fissile siltstone members predominating in the Nassau Siltstone, the limestone in the Berriedale Limestone and the siltstone in the Grange Mudstone. In essence there is an increase in lime content up to some part of the Berriedale Limestone after which the lime content decreases.

Nassau Siltstone

The Nassau Siltstone is defined as that formation of siltstone and limestone, with the siltstone predominating, which overlies the Rayner Sandstone and underlies the Berriedale Limestone on the northern flank of Mt. Nassau, especially in Geiss Creek and along the access road to the eastern quarry. It is named after Mt. Nassau. The co-ordinates of the type section are 504·7 E-736·6 N. In the type section it is of the order of 40 feet thick. It contains numerous fossils, especially *Strophalosia* spp. and *Fenestella* spp. It is Permian, probably Artinskian, in age.

This formation had not been recorded until Banks in Hill (1955) reported it as the "Granton Siltstone". This name is, however, undesirable because of the previous use of the geographic term "Granton" for a limestone and a stage of the Permian, the synonymy of which will be dealt with later.

The formation consists of an alternation of fissile siltstones and non-fissile siltstones or limestone, with the siltstone members being thicker than the limestone members. The formation grades up into the Berriedale Limestone and in the absence of good sections it is impossible to define the top of this formation accurately.

In the Geiss Creek section this formation is poorly exposed. The lower 30 feet consist of an alternation of greenish-grey, fissile calcareous siltstone with tough medium-grey limestone. Both rock types are richly fossiliferous. There is then a gap of 15 feet before outcrops of limestone with some siltstones commence.

Thin sections of the siltstones were examined. The siltstone is composed of angular grains of quartz, some of which are strained, and contain rutile, and some show lines of inclusions outlining former rounded grains which had suffered regrowth before transport to their present site. Magnetite, muscovite, some biotite, calcite, carbonaceous matter, and chlorite are also present. Some grains of plagioclase were also noticed. The grains are equidimensional to bladed or even acicular and are angular, the only round material in the slide being productid spines. It is stratified in that there are fine-grained lenses of dark-coloured claystone and siltstone in a rock which is dominantly in the silt grade with some fragments up to fine sand grade. Sorting is poor with most of the grades present in about equal amount. Some rock fragments are present and include large pieces of quartzite, chlorite schist and a chloritic micaceous schist. However, only the fossil fragments are larger than sand grade and these are up to a couple of inches long. The fossil fragments include pieces of *Stenopora*, fenestellids, productid spines, echinoderm plates and pelecypods. A productid spine and a fenestellid zooecium were lined with granular calcite and the centre of the cavity filled with quartz. The rock is essentially an impure, productid, fenestellid siltstone.

Examination of a thin section of one of the limestones near the top of the Nassau Siltstone showed that it contained mainly fossil fragments and grains of quartz which were angular to sub-angular. Other minerals present include slightly kaolinised microcline, fresh plagioclase, muscovite, green biotite, brown biotite, magnetite, chlorite, and zircon. Fragments of quartz muscovite schist, limestone, and a fine-grained granite were also present. Fossil fragments include *Stenopora* productid spines and shells, foraminifera, pelecypods, ostracodes and echinoderm fragments. Several of the shells showed small tunnels filled with matrix suggesting the acvitity of some burrowing organism. There is some calcareous cement. The fossil fragments which were rather broken, were up to 15 mm. long but the largest non-fossil fragment was only a millimetre long and most rock and mineral fragments were a little less than this. The rock is a productid calcarenite with much mineral matter.

As will have been seen above, there are representatives of many phyla in this formation. The fauna is dominated by *Strophalosia*, *Fenestella* and *Stenopora*, especially the ramose forms with a small diameter. In the Rayner Creek section *Martiniopsis*, *Trigonotreta*, other spiriferids, *Schuchertella*, *Mourlonia* and *Euryphyllum* were identified.

Examination of Brill's section of the Berriedale Limestone in the Weily's Quarries (Brill, 1956, pp. 140) shows that above the sandstone at the base, correlated with the Rayner Sandstone, there is almost 17 feet of mudstone, shale, meta-bentonite and minor bands of limestone before the main body of limestone is reached. The authors suggest that this represents the Nassau Siltstone so that the Berriedale Limestone as defined here does not commence until Brill's unit 11. Brill noted the presence of aviculopectinids and *Dielasma* in this formation at Weily's Quarry. A formation, dominantly of siltstone, occurs below the Berriedale Limestone on Maria Island where it was called the Productus Zone by Johnston (1901) at St. Marys and Avoca, and it is suggested as a first approximation that these are equivalent to the Nassau Siltstone.

Berriedale Limestone

The Berriedale Limestone is defined as that formation composed dominantly of limestone which lies above the Nassau Siltstone, where that formation is present, or the Rayner Sandstone, in the absence of the Nassau Siltstone, and below the Grange Mudstone or where that formation is absent, the "Woodbridge Glacial Formation". In the Mt. Nassau section, here designated as the type section, it is about 150 feet thick. The co-ordinates of the type section are 506·3 E-736·8 N. It contains *Taeniothaerus subquadratus*, *Strophalosia jukesi*, *Lyroporella*, *Eurydesma cordatum* var. *sacculum*, *Ptcrotoblastus* and *Conularia derwentensis*. It is Permian, probably Middle or Upper Artinskian in age. The name is derived from quarries close to Berriedale where the limestone was quarried.

This formation has been referred to by a number of names and the synonymy is shown below:

Mt. Wellington Limestone
Gould (1866, p. 29).

Mountain Limestone
Wintle (1865).

Crinoidal Zone
Johnston (1901).

Berriedale Limestone
Voisey (1938, p. 315).
Brown (1953, p. 59).
Crockford (1951).
David (1950, p. 359).
Hale and Brill (1955, p. 231, &c.).
Brill (1956, pp. 131-140).
Ford (1956, p. 149).
Banks (1957*a* and 1957*b*).

Granton Stage
Voisey (1938, p. 313, &c.), includes Berriedale Limestone and other lower beds.
non Voisey (1949), probably part of Golden Valley Group.
David (1950), as Voisey (1938).

Granton Sub-Stage
Lewis (1946, pp. 22 *et seq.*).

Granton Limestone and Marl
Hills and Carey (1949, p. 31) for Berriedale Limestone and the limestone on the shoreline at Porter Hill (= Darlington Limestone).
Banks (1952, p. 66) as Hills and Carey with addition of correlation with the Lower Marine Series of New South Wales.

Granton Formation
Fairbridge (1953) as for Granton Stage of Voisey (1938).
Hosking and Hueber (1954) as Voisey (1938).

Granton Limestone
Hale (1953, pp. 107, 8, 10).
non Ford (1954, pp. 153, 157, 158) which is Woody Island Siltstone and contiguous formations.

Gray Stage
Voisey (1938, p. 323) limestone part only.

Peter Limestone
Banks in Hill (1955, p. 89).

The Berriedale is an important horizon for mapping in the Hobart district and for correlation in the eastern part of the state. It is richly fossiliferous and many of the fossils described from the Permian near Hobart come from it.

The formation consists essentially of an alternation of fissile siltstones and non-fissile limestone, the limestone predominating. In addition metabentonite is present (Hale and Brill, 1955) on several horizons. The siltstone is similar in field appearance to that in the Nassau Siltstone. The limestone types in the Berriedale Limestone are varied. There are productid-fenestellid limestones, stenoporid limestones, crinoidal calcirudites and calcarenites, spiriferid-pelecypod limestones and calcilutites of several types. The limestones are seldom pure, as there is usually much clastic material of sand grade or even larger with erratics of quartz, igneous rocks and metamorphic rocks up to a foot in length in the limestone (Brill, 1956). Only one of these showed striations when examined by Brill but many of them are facetted. Occasional nodules of pyrite are present. Usually bedding is thick to very thick with thin to very thin bedding in the intercalated mudstone. The bedding planes, where they are well exposed in quarries, are frequently wavy, probably due to ripple marking.

Thin sections showed that one bed of limestone was composed of fragments of *Stenopora, Fenestella*, productid brachiopods, spiriferids, pelecypods, ostracodes and echinoderms. Siliceous sponge spicules, monaxons, were recognized. Some of the fossil fragments show solution along narrow tunnels and infilling with groundmass suggesting the action of some burrowing organism. Some of the fragments, especially the echinoderm pieces, show rounding. Rare grains of sericitised feldspar, magnetite and rounded fragments of green biotite are also present. The rock is well sorted with most of the fossil fragments in the sand grade with a few fragments in the granule and one in the pebbie grade. The mineral particles are of sand grade. Much of the groundmass is recrystallised and is now a mosaic of calcite grains. This rock is a bryozoal calcarenite.

The type section for this formation should be in the Berriedale Quarries or in that vicinity but the structure there is not yet clear. The longest quarry exposure is at Weily's Quarry, Tolosa Street, Glenorchy (see Brill, 1956, for section, also text figure 7), but the underlying and overlying sections are not well exposed. At Mt. Nassau the formations above and below the limestone are present but again not well-exposed so that only the total thickness of the Cascade Group can be measured with any accuracy at about 300 feet. Of this about 40 feet at the base is Nassau Siltstone and then there is at least 50 feet of limestone exposed in the quarries but neither the bottom or the top of the limestone is included in the quarries. From poor exposures on the hill slopes it would appear that there is about 50 feet of this formation above and below the quarries making a minimum thickness of 150 feet but there may be more than this due to the difficulty of finding the boundary between the Berriedale Limestone and its contiguous formations in the absence of cliff or quarry sections. Brill (1956) has published sections through this formation in a number of places in the Hobart district and gave the details of the section at Weily's Quarry. Of this section the present authors would include units 11-60 only as the Berriedale Limestone—the higher units being considered here as the Grange Mudstone. This section is reproduced here in columnar form as text figure 6 which includes also the section measured by the authors in Geiss Creek, which is poorly exposed.

Fossils are abundant in this formation and represent almost every animal phylum as well as plants. Fragments of leaves and stems and pieces of fossil wood occur in it in places, e.g., Black Snake Gully Quarries, Granton, and the Rathbones Quarries, Mt. Nassau. Foraminifera are present at least at Weily's Quarry but have not been identified. Sponges have been identified in a section from Rathbone's Quarries. Corals occur also in the Rathbone's Quarries and include *Euryphyllum*. The brachiopod fauna is very rich and includes *Schuchertella, Taeniothaerus subquadratus* (Weily's Quarry, Berriedale Quarry and Rathbone's Quarries at least), *Strophalosia jukesi, Grantonia hobartense, Trigonotreta stokesii, Martiniopsis*, and *Dielasma*. Bryozoa include *Polypora woodsi, Stenopora pustulosa, S. hirsuta and Steno-*

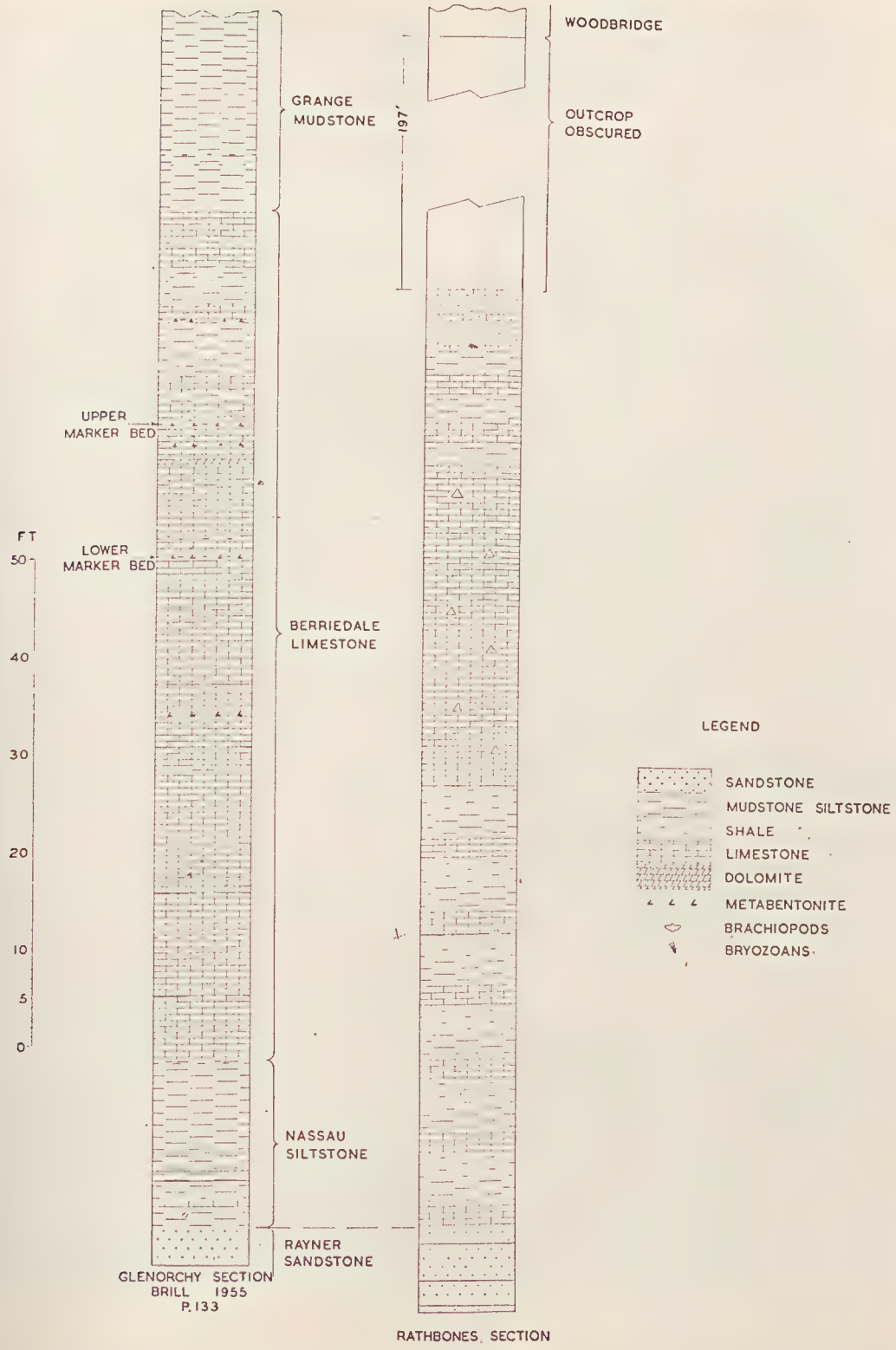

WOODBRIDGE
OUTCROP OBSCURED
197'
GRANGE MUDSTONE
UPPER MARKER BED
LOWER MARKER BED
FT
50
40
30
20
10
5
0
BERRIEDALE LIMESTONE
NASSAU SILTSTONE
RAYNER SANDSTONE
GLENORCHY SECTION
BRILL 1955
P.133
RATHBONES SECTION
LEGEND
SANDSTONE
MUDSTONE SILTSTONE
SHALE
LIMESTONE
DOLOMITE
METABENTONITE
BRACHIOPODS
BRYOZOANS

Fig. 7

discus moniliformis from the Berriedale Quarries and *Stenopora pustulosa, Polypora magnafenestrata,* and *Fenestella fossula* from Weily's Quarry. The bryozoa quoted are only those determined by Crockford in a series of papers summarized in 1951. Only one further bryozoan should be mentioned, *Lyroporella,* which has been found so far in the Hobart area at Rathbone's Quarries and at the Berriedale Quarries. Pelecypods are common and include *Astartila, Deltopecten limaeformis* and *D. subquinquelineatus, Aviculopecten englehardti, A. mitchelli, A. sprenti* and *A. squamuliferus,* from the Berriedale Quarries. *Eurydesma cordatum* var. *sacclum* has been found in the Mt. Nassau section and also in the Black Snake Gully Quarries. Many other pelecypods are present and have been recorded by authors last century, the only ones quoted being recent determinations. Gasteropods are not so common but many are present and include *Mourlonia morrisiana* from both Berriedale Quarries and the Mt. Nassau section. There are numerous undetermined ostracodes. A blastoid, probably *Pterotoblastus,* has been found at Rathbone's Quarries and at Berriedale Quarries. Crinoid elements are very common and have been identified as belonging to *Calceolispongia noetlingi,* and *Camptocrinus tasmaniensis* in the Mt. Nassau and/or Black Snake Gully Quarries. There are probably other species as well. Interambulacral plates and spines of *Archaeocidaris* have been found at Rathbone's Quarries. Although *Conularia* is not common it is represented by one large species, *C. derwentensis* which occurs at the Black Snake Gully Quarries and Rathbone's Quarries at least.

Of these fossils *Taeniothaerus subquadratus, Lyroporella* and *Pterotoblastus* can be easily identified and one or more of them are found in the Crinoidal Zone on Maria Island, the Peter Limestone at Coles Bay and the Gray Stage Limestone at St. Marys, the Enstone Park Limestone north of St. Marys, at Fingal, and at Avoca. In the Hobart sections these fossils occur low in the Berriedale Limestone. *Euryphyllum* in Tasmania is restricted to the lower parts of the Cascades Group and occurs in that position in the Mt. Nassau section, on Maria Island, at Coles Bay, St. Marys and north of St. Marys. Thus the limestones at these places are correlated with the Berriedale Limestone although exact equivalence is not suggested. The matter of the correlation of the Berriedale Limestone within Tasmania has been dealt with elsewhere in more detail (Banks, 1957*a*).

Some of the bryozoans, brachiopods, and pelecypods suggest a correlation of the Berriedale Limestone with some part of the Branxton Sub-Group in the Maitland Group of New South Wales and the Cattle Creek and/or Ingelara Stages in Queensland. The correlation with Western Australia is not at all certain for although there are some Westralian elements in the fauna these have not yet been studied. Interstate correlations have been dealt with by Banks (1957*a*) in more detail.

The comparative lack of clastic material in this formation probably indicates a lower land surface than during the deposition of the earlier formations. The erratics would indicate that icebergs were floating about in the sea and slowly melting. and their number and composition suggest derivation from a westerly or north-westerly direction (see Brill, 1956). As Brill has pointed out (1956), the cycles of limestone and mudstone in this formation could be due to several causes. In view of the common occurrence of glacial deposits in the Permian of Tasmania and the comparative rarity of pyroclastic deposits Brill's fourth hypothesis is thought to be the most likely. This is, namely, that the changes in the rate of sedimentation (or type of sediment, authors) may reflect the waxing and waning of glaciers. Thus the limestone (calcarenite) beds would represent times of increased current activity and shallower water and presumably also of increased supply of material from an uplifted surface on which glaciers are retreating and stream erosion is greater, while the mudstone beds represent periods of glacial advance, lower land surfaces and smaller stream capacities. Brill's observation that the erratics tend to occur in the mudstone or in the limestone close to the mudstone supports this hypothesis. The depth at which the limestone was deposited seems to have been variable. There is some evidence of ripple-marking, but this cannot be used as a depth criterion. The occurrence of calcarenites and crinoidal calcirudites suggests fairly strong currents as also does the weight and coarse ornamentation of the pelecypod and spiriferid shells. Stenoporid and fenestellid zoaria are usually broken. On the other hand the productids often occur in the mudstones with their spines still attached and some complete fenestellid colonies have been found associated with them. This indicates very quiet deposition for the mudstones. Normally limestone is considered as a warm water deposit but the presence of erratics suggests cold water condition. At the present time icebergs drift as far north as 35° S in the Atlantic where the surface temperature in the summer is about 20° and the bottom temperature about 10°. This provides some idea of the maximum temperature at which the Berriedale Limestone might have been deposited. In view of the number of erratics in the formation it is probable that the limestone was deposited closer to the edge of the Permian ice-sheet than this limit of 1600 miles. From the evidence of the areal distribution of the limestone and the nature of the erratics it is probable that the land with the ice-sheet was of the order of 100-200 miles away in which case the temperature would have been much lower on the sea floor, probably only a few degrees above zero centigrade. The simple horn corals which occur in this formation suggest deposition in cold, deep or murky water (Hill, 1948), and the foraminifera are mainly arenaceous types, again suggesting cold or deep water. The large size and weight of many of the pelecypod shells would normally be taken to indicate that they lived in warm water. However, it seems possible that some of the pelecypods, e.g., *Eurydesma cordatum,* and the brachiopods, e.g., *Taeniothaerus subquadratus,* may have been adapted to cold conditions and produced bigger, heavier shells in the colder seas. The consistent association of *Eurydesma* with glacial deposits throughout the Gondwana countries supports this, as also does the fact that the shells of *T. subquadratus* are thinner in Western Australia, where glaciation was less severe, than in Eastern Aus-

tralia (see Prendergast, 1943). Thus the bulk of evidence suggests deposition in fairly quiet, cold water of varying depth.

Grange Mudstone

The Grange Mudstone is here defined as that formation of siltstone and calcareous siltstone which overlies the Berriedale Limestone, or where that formation is absent, the Rayner Sandstone, and underlies the "Woodbridge Glacial Formation". In its type area, at Porter Hill, Sandy Bay, it is about 290 feet thick. The co-ordinates of the type area are 521·5 E-715·5 N.

The formation is named after the Grange Quarry, the beds in which are continuous along the strike with the beds at Porter Hill, about half a mile to the north. It is richly fossiliferous, *Strophalosia* and fenestellids, including *Polypora woodsi*, being particularly abundant. It is Permian, probably Middle or Upper Artinskian, in age.

This formation has been known under one name or another since Johnston (1888, p. 118) referred to it as the "*Fenestella* Zone". Usage since that date is detailed hereunder:—

Fenestella Zone
Johnston (1888, p. 118), Cascades, Porter Hill and Grange, *non* Maria Island.

non Fenestella Zone
Montgomery (1891); beds below Crinoidal Zone on Maria Island.
Johnston (1901); as Montgomery 1891.

non Fenestella Shales
Gregory (1905), formation at top of Junee Group (Ordovician) at Gormanston.

Grange Stage
Voisey (1938, p. 313).
non Voisey (1949, p. 106), probably Golden Valley Limestone and Shale.
David (1950, p. 359-360).

Grange Mudstones
Hills and Carey (1949, p. 31).
Banks in Hill (1955, p. 89).

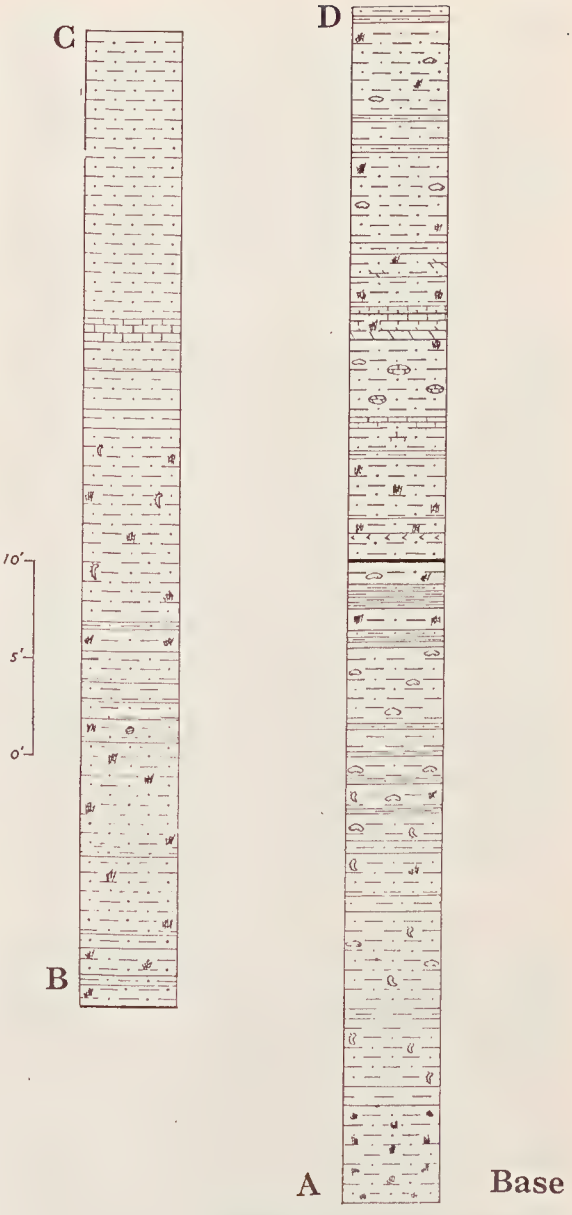
Grange Sub-Stage
Lewis (1946, pp. 22 *et seq.*).

Grange Facies
Prider (1948, p. 173), probably partly equivalent.
Fairbridge (1949, pp. 114, 5, 6), probably partly equivalent.

Grange Mudstone
Banks (1952, p. 67).
Hale (1953*a*, pp. 107 et seq.).
Ford (1954, p. 154).
Hale and Brill (1955, p. 233).
Mather (1955, p. 193).
Brill (1956, p. 135).

Grange Formation
Fairbridge (1953).
Hosking and Hueber (1954).

The Grange Mudstone consists essentially of siltstone, calcareous siltstone and minor beds of limestone, dolomite and nontronite. The section at the Grange Quarry which is the best exposure in the type area is here published in columnar form as text figure 8 with the kind permission of K. G. Brill, who measured it.



SECTION OF GRANGE MUDSTONE
GRANGE QUARRY
AFTER K.G. BRILL

Fig. 8

This section is not quite as long as that at Porter Hill but is better exposed. The top of the section is missing at Grange Quarry, being replaced by a transgressive dolerite body. The lithology of the formation has been described by Voisey (1938),

Lewis (1946), Banks (1952), Hosking and Hueber (1954) and Hale and Brill (1955). One of the characteristic features of the formation is the creamy (moderate yellow to greyish-yellow) colour of many beds and the abundance of *Strophalosia* and fenestellids which produce the appearance of lamination. The formation was apparently particularly susceptible to intrusion by dolerite with the production of contact metamorphic effects. As a result the calcite of the shells is often recrystallised and diopside and other calc-silicate minerals develop. In addition to this there is extensive silicification so that both calc-silicate and siliceous hornfelses are produced.

Thin sections were cut of two of the limestones of this formation from Mt. Nassau. Both are calcilutites with an abundance of *Strophalosia*. One section consists of numerous shell fragments up to pebble size, but mainly in the sand grade, with fragments of quartz of sand grade in a groundmass of silt and clay grade grains of calcite with a little quartz. The groundmass is not uniform in grain size, there being irregular areas of clay grade in the groundmass which is dominantly silt grade. Most of the grains of quartz are angular. Fragments of quartz muscovite schist and other rocks are also present. Angular, often bent, grains of green biotite, magnetite and small grains of zircon are present. The shell fragments which show resorption in some cases include those of productid spines, a perforate uniserial foraminifera, pseudopunctate brachiopods, pelecypods, *Stenopora* and rare fenestellids. The other section is that of a well-bedded limestone with beds of fine calcarenite and fine calcilutite. The calcite grains in the calcarenite are mostly recrystallised. Angular grains of quartz of fine sand grade are present. The shell fragments are mainly fenestellids but some braciopod spines and fragments of pseudopunctate shells, pelecypod fragments and *Stenopora* are also present.

At Porter Hill the Grange Mudstone overlies about 20 feet of medium-grey, richly fossiliferous, foetid limestone which is lithologically like the Berriedale Limestone. This thin limestone unit overlies a bed of sub-greywacke sandstone which is about ten feet thick and similar to the Rayner Sandstone. Over the thin limestone unit there is typical Grange Mudstone which continues upwards for about 290 feet (Abney level figure) but in several places contains beds of greyish limestone up to two feet thick. These limestone beds are quite subordinate as will be seen also from the columnar section, based on exposures at the Grange Quarry. Above the Grange Mudstone at Porter Hill is a conglomeratic sandstone with rare marine fossils and plant fragments, which is lithologically very like the sandstone at the base of the "Woodbridge Glacial Formation" at Mt. Nassau. At the Cascades there is again an association of creamy mudstone, rich in fenestellids and *Strophalosia* with medium-grey limestone with spiriferids and pelecypods. There the association, which becomes dominantly creamy mudstone near the top, is overlain by sandstone at the base of the "Woodbridge Glacial Formation". This latter formation can be traced up into the Risdon Sandstone and Ferntree Mudstone in this area. At Weily's Quarry, Glenorchy, Brill (1956, p. 138) shows the Berriedale Limestone overlain by the Grange Mudstone. The authors would prefer to take the Grange Mudstone down to include unit 61 of Brill's section, taking as the base of the Grange Mudstone, the first bed above the point where mudstone becomes dominant over limestone in thickness. Grange Mudstone overlies the Berriedale Limestone and underlies the "Woodbridge Glacial Formation" at the Berriedale Quarries but the section at this locality is not at all clear. At Mt. Nassau the Berriedale Limestone in the quarries is overlain by about 50 feet of limestone before the Grange-type mudstones appear to become predominant. The exact horizon where this takes place cannot be determined due to poor outcrop but there is about 100 feet of Grange Mudstone in this section making the total thickness of the Cascades Group about 300 feet. The Grange Mudstone in this section is overlain by a sandstone at the base of the "Woodbridge Glacial Formation". Throughout the Hobart area then, creamy, fenestellid, *Strophalosia*-rich mudstones with very subordinate limestones overly the Berriedale Limestone directly and underly the "Woodbridge Glacial Formation'. They increase in thickness from Mt. Nassau south to Sandy Bay at the expense of the lower formations of the Cascades Group which maintains a fairly constant thickness throughout this area. Thus while the Grange Mudstone always overlies the Berriedale Limestone where this latter formation is present, it also appears to occupy progressively more and more of the stratigraphical position of the Berriedale Limestone to the south until at Snug and other places in the south-east the Cascades Group consists only of the Grange Mudstone. Thus on stratigraphical evidence it is suggested that the Berriedale Limestone and the Grange Mudstone are to a considerable extent facies variants, the one of the other. On the stratigraphical evidence presented other interpretations are also possible, for example, it is possible that the Berriedale Limestone was deposited in its entirety before deposition of the Grange Mudstone began and that the areal distribution of the limestone and its thickness variations may be in no way related to the distribution and variation in thickness of the Grange Mudstone.

The Grange Mudstone is richly fossiliferous. It is interesting to note that Johnston (1888, p. 118) recorded *Taeniothaerus subquadratus* from his *Fenestella* Zone, now called the Grange Mudstone, at either Cascades, Porter Hill or the Grange. As this fossil is restricted to a narrow zone within the Berriedale Limestone in Tasmania, this record suggests that the two formations are at least partly equivalent. The present authors have not yet been able to verify this report, nor to find *Lyroporella* or *Pterotoblastus* in the Grange Mudstone, but there is a strong possibility that these fossils are restricted to the limestone facies in Tasmania. From the Grange Quarry, Fletcher (in Voisey, 1938) recorded *Deltopecten subquinquelineatus*, *Platyschisma oculus* and *Mourlonia morrisiana* as well as numerous other fossils. From Fletcher's list it will be seen that every species listed from the Grange Quarry, with the exception of *Platyschisma oculus*, occurs also in the Berriedale Limestone at Collinsvale Lime Kilns (referred to in this paper

as the Berriedale Quarry) and at Granton (either the Black Snake Gully or Rathbone's Quarry, or both). Voisey's fossil localities 6 and 7 (1938, p. 326) are not now considered as equivalent to the Grange Mudstone but to the richly fossiliferous beds just below the top of the "Woodbridge Glacial Formation". From the Grange Quarry, Crockford (1951) recorded the bryozoa *Fenestella dispersa, F. fossula* and *Polypora woodsi*, all of which also occur in the Berriedale Limestone (Crockford, 1951, pp. 110, 111). *Polypora woodsi* is restricted to part of the Branxton Sub-group in New South Wales but has a longer range in Queensland and Western Australia apparently. It is remarkable that although *Wyndhamia dalwoodensis* (equals *Strophalosia typica* is regarded as characteristic of the Grange Mudstone by Voisey (1938, p. 328), on the list of fossils in his paper it is recorded from the Berriedale Limestone in two places and from the richly fossiliferous horizon just below the top of the "Woodbridge Glacial Formation" on Mount Faulkner, but not from Grange Quarry. Both Voisey (1938) and Crockford (1951) suggest correlation of the Grange Mudstone with the Branxton Sub-group of New South Wales and Banks (1957*a*) has suggested that the Berriedale Limestone is also at least partly equivalent to the same sub-group. Recorded fossil evidence thus also supports the hypothesis that the Berriedale Limestone is at least partly a facies variant of the Grange Mudstone but further work is necessary before the hypothesis can be regarded as proved, Hills and Carey (1949, p. 31) state that there is considerable facies variation between sections of their Cascades Formation, but this term has a much wider meaning than the Cascades Group as here used, and it is not clear that they envisaged the facies variation postulated here.

"Woodbridge Glacial Formation"

It is not appropriate here to define the formation between the top of the Cascades Group and the base of the Risdon Sandstone as another worker who has studied the formation over a wide area hopes to do this shortly.

In the Mt. Nassau section the Cascades Group is overlain by a formation of sandstone and siltstone which is about 275 feet thick (measured with Abney level) and overlain by the Risdon Sandstone. At the base is a conglomeratic sandstone which contains numerous erratics and fossils, except bryozoa, which are rare. About 60 feet above the base the formation becomes finer-grained and is dominantly siltstone with numerous sandstone bands. In this part of the formation the fossils become uncommon, and although erratics are present they are not very common, and there is no really tillitic bed. About 50 feet from the top of the formation there is a bed of siltstone which is very rich in fossils, mainly productids but with some spiriferids and pelecypods. This bed is only a few feet thick. Lenses of limestone occur in the formation on Mt. Nassau from 23 feet to 21 feet 6 inches below the top of the Risdon Sandstone. The measurement is given in this form because the top of the "Woodbridge Glacial Formation" is hidden by talus. However, this would mean that the limestone lenses are between 13 feet and 11 feet 6 inches from the top of the formation. The limestone lenses are at least 18 inches thick and the rock is olive-grey, foetid and fossiliferous. The fossils include *Martiniopsis, Stenopora crinita, Strophalosia, Mourlonia* and fenestellids.

In the main part of the "Woodbridge Glacial Formation" the commonest fossils are spiriferids and pelecypods and plant fragments are also common. A very alate spiriferid is common in the formation and occurs in the excavations for the Lake Fenton Pipeline above Rathbone's Quarries.

Thin sections were cut of several rock tyes in the formation on the flanks of Mt. Nassau. The sandstone at the base contains much quartz, some feldspar (slightly weathered orthoclase, microcline and andesine), muscovite and green biotite. Accessory minerals include ilmenite, sphene, zircon, tourmaline (schorlite) and rutile. The groundmass is composed of quartz, muscovite, chlorite and limonite. Rock fragments are common and include micaceous quartzite, haematitic quartzite, mica schist, graphitic mica schist and muscovite gneiss. Some of the quartz grains contain zircon crystals, some contain muscovite, some show undulose extinction and some show regrowth, one piece having two rings of inclusions inside an angular grain. Rutile occurs as grains in the rock and also as crystals in quartz grains, one of these being twinned in the characteristic fashion. Most of the zircon is angular, but some is sub-rounded, some is in the form of crystals and some shows regrowth. The rock is a fine sandstone, average grain size about 0·25 mm. The largest grain present in the slide is a pebble (4·5 mm.) and there are small interstitial patches of very fine siltstone (0·015 mm.). The grains are mostly highly angular, and many have sutured boundaries with neighbouring grains, so that the overall texture is mosaic. There is no obvious preferred orientation. The rock is a conglomeratic, somewhat impure, partially recrystallised sandstone.

A siltstone from higher in the formation contains grains of quartz microcline, andesine, microperthite, chlorite, mica flakes and zircon. The total feldspar content is only about 5 per cent. Fragments of mica schist with tourmaline, quartz biotite schist (green biotite), and a rock with feldspar phenocrysts with rude flow structure are present. The grains are dominantly in the silt grade (about 0·015 mm.) but fragments up to 0·56 mm. long are present and much of the groundmass is probably in the clay grade. Sorting appears to be poor. The larger grains are mainly angular to sub-angular but some are sub-rounded. Rounding appears to be a little better in the finer grades. Most of the grains are equant, but a few, especially the micas, are bladed to almost acicular.

The limestone from close to the top of the formation is composed of fragments of quartz and shell material. The shell fragments are up to 2 mm. long but the quartz grains are smaller, from 0·03 to 0·25 mm. only. The groundmass is of calcite and quartz fragments mainly of fine silt grade but with some in the clay grade. There are angular fragments of quartz, plagioclase, green biotite, magnetite, chlorite, microcline and muscovite and some of the quartz grains are almost cuspate. Some of

the quartz contains zircon. The shell fragments some of which show resorption, include productid spines, foraminifera, pelecypods and probably ostracodes. It is essentially a productid calcilutite.

No attempt will be made here to deal with the conditions of deposition of this formation except to point out the predominance of metamorphic types in the rock fragments and of the minerals derived from these. These appear to be more like the Precambrian rocks than any later rocks in Tasmania. There is evidence also of derivation of some of the sediment from pre-existing sediment and of some from a granitic and pegmatitic terrane. There has been extensive recrystallisation of the rock, particularly of the sandstone at the base with its mosaic texture.

Risdon Sandstone

The Risdon Sandstone is here defined as that formation of feldspathic sandstone which lies between the "Woodbridge Glacial Formation" below and the Ferntree Mudstone above, in the Mt. Nassau section. The type area is in a road cutting on the north-east side of the road up Risdon Creek near Bowen's Monument, about two chains from its junction with the Risdon-Richmond Road. The co-ordinates of the type area are 519·4 E-719·2 N. The name is derived from the village of Risdon. It is ten feet thick. It is Permian, probably Upper Artinskian or Lower Kungurian, in age.

This name was first used by Carey and Henderson in an unpublished report to the Mines Department in 1946 for the basal member of the Ferntree Mudstone. It has been used since in that sense by Carey (1947, p. 32) (the first published use of the term), Prider (1948, p. 134), Hills and Carey (1949, p. 32), Voisey (1949, p. 106), Banks (1952, p. 70), Hale (1953, p. 20; 1953*a*, p. 107) Ford (1954, p. 154), Hale and Brill (1955) and Mather (1955). It is a very widespread, easily recognizable and very mappable unit and for these reasons is here considered as a formation.

On the flanks of Mt. Nassau it is present as a bench-making horizon and shows the characters described earlier by Banks (1952, p. 71). One feature not noted earlier is the occurrence of tubicolar casts perpendicular or at a high angle to the bedding in the Mt. Nassau section.

A section of this rock was examined and showed the presence of quartz, much plagioclase (20-25%), muscovite, zircon, haematite and limonite, as well as a few pieces of microcline, ilmenite, brown biotite, and tourmaline. The plagioclase includes albite and andesine, and there is one piece of quartz and microperthite present. Rock fragments are not common but there are a few including a piece of quartzite. Most of the grains are about 0·16 mm. long with a few grains up to 1 mm. long and a small amount of finer material. Most of the grains are angular but there are a few sub-angular grains present. The grains are dominantly equidimensional but a few are tabular. Many of the grains have developed sutured outlines by regrowth so that a mosaic texture is produced. The rock on Mt. Nassau is a richly feldspathic sandstone.

Ferntree Mudstone

The Ferntree Mudstone may be defined as that formation consisting dominantly of an alternation of fissile and non-fissile siltstone which overlies the Risdon Sandstone and underlies the Cygnet Coal Measure or, where these are absent, the Knocklofty Sandstone and Shale of the Triassic System. It is 600 feet thick. The formation is named after the village of Ferntree where it outcrops (co-ordinates 512·6 E-715·9 N) and which should be the type area. The formation is Permian, probably Kungurian, in age.

This formation has received a number of different names since Johnston (1888, p. 118) referred to it as the Mudstone Zone. The synonymy is as follows:

Mudstone Zone
Johnston (1888, p. 118).

Upper Marine Series
Johnston (1888, p. 118).

Lindisfarne Stage
Voisey (1938, pp. 313 *et seq.*).
David (1950).
non Lewis (1946); for "Woodbridge Glacial Formation".

Lindisfarne Mudstone
Carey (1947).

Ferntree Mudstone Stage
Lewis (1946, pp. 22 *et seq.*).

Ferntree Mudstones
Carey (1947, pp. 32, 33, 36).
Hills and Carey (1949, p. 32).

Ferntree Formation
Prider (1948, pp. 127 *et seq.*).
Ford (1956, p. 150).

Ferntree Stage
Voisey (1949, pp. 106, 108).

Ferntree Mudstone Formation
Fairbridge (1949, pp. 114, 118).
Fairbridge (1953).

Ferntree Mudstone
Banks (1952, pp. 70 *et seq.*).
Hale (1953*a*, pp. 98 *et seq.*).
Brill and Hale (1954, pp. 279, 281).
Ford (1954, pp. 155 *et seq.*).
Ford (1954*a*, p. 185).
Hale and Brill (1955, pp. 233-4).
Jennings (1955, pp. 172 *et seq*).
Mather (1955, pp. 193 *et seq.*).

In the Mt. Nassau section the Ferntree Mudstone consists of an alternation of fissile and non-fissile siltstone but the exposures are not good and detailed stratigrahic work could not be done. Exposures in the Ferntree district are rather better because of the presence of numerous road cuttings but still not good enough for preliminary detailed measurement due to very complex faulting and a thick cover of vegetation. The best section avail-

able in the Hobart area is probably in the bed of New Town Creek and it is hoped to measure this in detail shortly.

In the Mt. Nassau section the Ferntree Mudstone is 600 feet thick but this may not represent the total thickness of the formation as the next highest formation, the Cygnet Coal Measures, does not outcrop in this section. This lack of outcrop may be due to erosion before the deposition of the Triassic System or to non-deposition, but no choice can yet be made between the alternatives although the erosional hypothesis is supported by disconformities between the Ferntree Mudstone and the Triassic System in at least two places in the Huon district. Lewis (1946, p. 94) gives a section in New Town Creek and it is notable that in it there are 25-30 feet of Cygnet Coal Measures. The lack of Cygnet Coal Measures at Mt. Nassau may be apparent rather than real as the outcrop near the top of the Ferntree Mudstone is very poor and the coal measures could be covered by talus.

It is not proposed to give a full description of the Ferntree Mudstone on Mt. Nassau but to wait till the detailed section is measured in New Town Creek. Observations on this formation in the Mt. Nassau section which have not earlier been recorded are that marine fossils occur sparsely but are particularly noticeable just above the base and again about 400 feet above the base. Even at these levels they are not common. Spiriferids are the commonest types. Worm tubes are common.

Examination of a thin section showed that the siltstone consists of rock and mineral fragments up to 1 mm. in length in a groundmass about 0·02 mm. in average grade. It is not well-sorted as all intermediate grades appear to be present in about equal amount. The fragments are very regular to almost cuspate and tend to be tabular or bladed rather than equant and a few are prolate. There are signs of rude bedding in the rough orientation of fragments. Quartz is the dominant mineral but microcline, plagioclase, muscovite and a small amount of biotite are also present. The groundmass is haematitic. Rock fragments are also present and include quartzite and micaceous quartzite.

As has been remarked earlier, the beds at the top of the Bundella Mudstone, the Jarvis Siltstone, the Fergusson Siltstone and the Ferntree Mudstone are all lithologically very similar and this suggests recurrence of similar conditions at those levels. It has been suggested earlier (Banks, 1952) that the Ferntree Mudstone was deposited in brackish, shallow, possibly estuarine conditions with occasional access of ice-bergs. Such conditions would seem to satisfy all that is known about the other formations and also their position in the cyclothems.

SUMMARY

On the northern slopes of Mt. Nassau about 1430 feet (1436 as measured) of Permian sediments are exposed in an uninterrupted sequence. This is the best section known in the Hobart district for the Permian succession but in other places exposures of individual formations are better. The Geiss Creek section is particularly noteworthy for the fine exposures of the formations below the Berriedale Limestone.

The succession is summarized in columnar form as text figure 9:

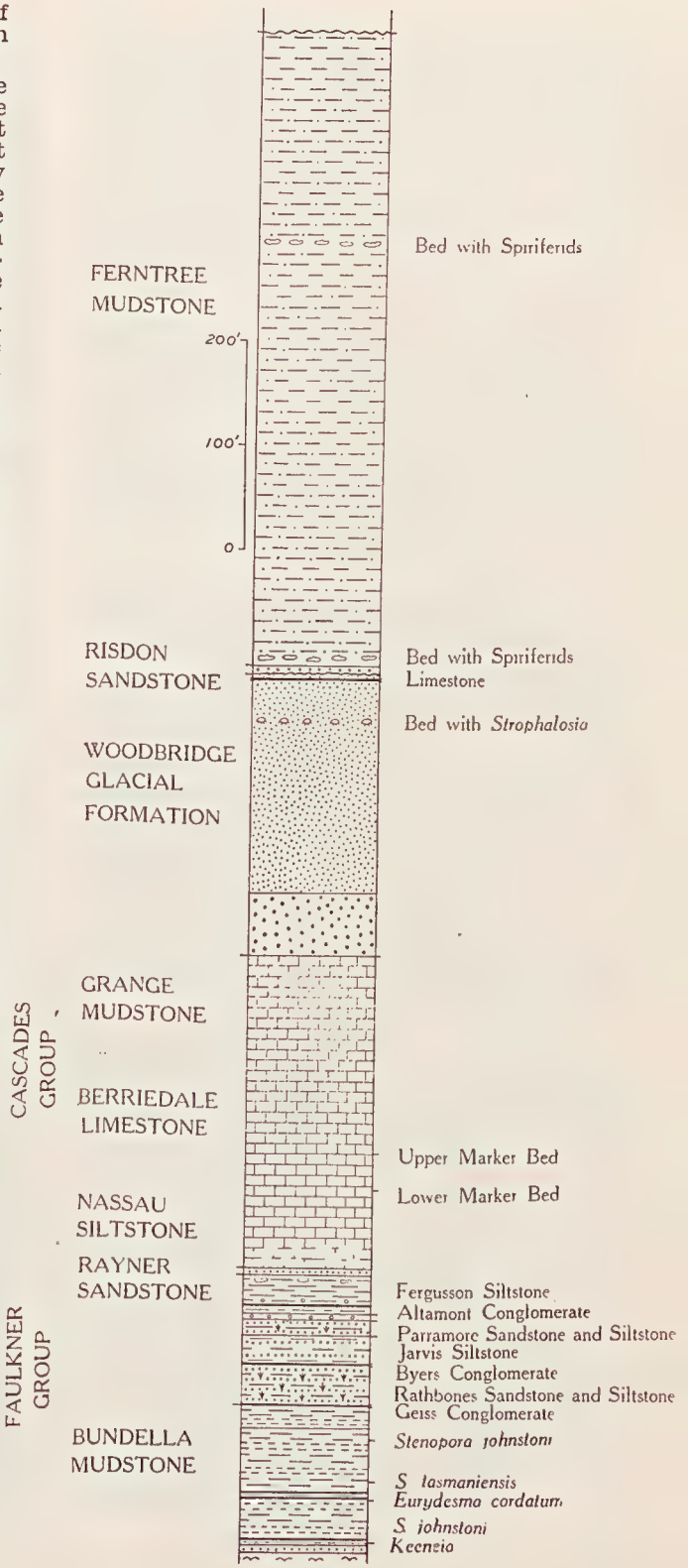


Fig. 9

Unfortunately the section does not reach the base of the Permian as developed in Tasmania but correlation of the basal formation in this section with beds on Maria and Woody Islands suggests that it is underlain at no great depth by the Darlington Limestone beneath which is the sequence on Woody Island, about 300 feet thick, and below that again the basal beds in the Florentine Valley, about 200 feet thick. On top of the section in some places is the Cygnet Coal Measures, about 300 feet thick, giving a maximum thickness for the south-eastern Permian as about 2250 to 2300 feet. The correlations involved, as well as the successions, have been dealt with by Banks (1957*a*).

The succession on Mt. Nassau probably begins in the lower part of Artinskian, judging from correlations of the Darlington Limestone with beds in New South Wales and Western Australia, and the ages determined on the beds in the other States, especially on the ammonities in the Western Australian succession. On bryozoan evidence Crockford (1951) considered the "Woodbridge Glacial Formation" at Eaglehawk Neck to be basal Kungurian, so that the higher formations are probably Kungurian or possibly younger.

Of special significance is the occurrence of the fresh water beds in the Faulkner Group, signifying a period of emergence, broken here by a minor submergent phase, in the general submergence during the Permian. The Permian succession in south-eastern Tasmania when considered as a whole show initial deposition of tillite on a land surface, then marine deposition, an emergence, followed by another submergence and finally an emergence. This sequence of events has considerable parallel with those in the Permian in New South Wales but whether similar events were actually contemporaneous in the two areas is not yet established. There is some evidence from correlation already made that they could have been roughly simultaneous. The parts played in the movements of sea level in Tasmania by glaciation and by tectonic activity cannot yet be elucidated. The Faulkner Group is considered to consist of two cyclothems.

While the Berriedale Limestone is overlain by the Grange Mudstone in many places, there is stratigraphical and palaeontological evidence that the Berriedale and Grange Formations are equivalent in age and that the Berriedale Limestone is replaced in stratigraphic position to the south-east by the Grange Mudstone. Thus the two formations are considered to be at least partly facies variants of one another.

Mineralogically the sediments in this section are remarkably constant and even in the limestones some of the characteristic minerals occur. There does not seem to be any change in overall mineral composition from bottom to top of the section. Quartz is the most common mineral and several varieties are present. Quartz with undulose extinction, quartz with rutile inclusions, quartz with zircon inclusions and quartz showing up to two zones of inclusions indicating regrowth are all present. The dominant feldspar present is microcline but orthoclase, albite, andesine and microperthite are also present, andesine being more common than the others. In most formations the feldspar forms less than 10 per cent of the rock, but in the Risdon Sandstone up to 25 per cent is present. The micas include muscovite, the commonest type, green biotite and brown biotite. Minor amounts of chlorite, clay minerals and carbonaceous matter occur in several formations and hydrated iron oxides occur in most formations. Heavy, accessory minerals include zircon, apatite, tourmaline (usually schlorite), garnet, ilmenite, magnetite, pyrite, epidote and rutile. Calcite is common on several horizons and dolomite has been noted in the Grange Mudstone. Montmorillonite occurs in the Berriedale Limestone and nontronite in the Grange Mudstone. The presence of up to 10 per cent of fresh feldspar in most formations, except the Rathbones and Parramore Formations, and up to 25 per cent in the Risdon Sandstone indicates some mineralogical immaturity in the sediments. The minerals suggest that the Permian sediments were derived from a terrain of granitic and pegmatitic rocks, quartzose sedimentary rocks and dynamically metamorphosed rocks. Contemporaneous volcanic activity is suggested by the presence of montmorillonite in the Berriedale Limestone.

Inferences based on the mineralogy of the sediments as to the provenance are confirmed and amplified by the types of erratics present.

The erratics include granite, feldspar porphyry and large pieces of vein quartz, limestone, mudstone, quartzite, micaceous quartzite, haematitic quartzite, slate, phyllite, muscovite schist, muscovite chlorite schist, quartz muscovite schist, quartz biotite schist (with green biotite), biotite schist, chlorite schist, graphitic mica schist, tourmaline-bearing mica schist, and muscovite gneiss. The metamorphic types are much commoner than the igneous or sedimentary types. The presence of these metamorphic rocks suggests a source within the Precambrian areas of Tasmania to the south-west, west or north-west of Hobart, and all of the rock types and minerals present could come from the Precambrian, Lower and Middle Palaeozoic rocks of the western half of Tasmania. There is on the other hand no evidence of rocks from the north-eastern part of the State. None of the erratics noted are such that specific localities of origin can be allocated to them.

With some exceptions to be dealt with shortly the rocks of the section all show some common textural features, namely the poor sorting, exemplified megascopically by the presence of erratics, lack of cross or graded-bedding, and marked angularity of grains, many of which are almost cuspate. In conjunction with the mineralogical immaturity these features could be taken to indicate tectonic instability in the source and depositional areas, but the shape of the beds (tabular) and known distribution of thickness of beds and formations indicates a fairly stable depositional area. The presence of numerous erratics and fresh feldspar indicate that disintegration predominated over decomposition in the source area and that glaciers and icebergs were important in transporation. This mode of transport is supported by the texture

of the rocks. Deposition apparently occurred below wave base as shown by the poor sorting and lack of current or wave structures. This does not necessarily mean deep water. Slump structures are uncommon and graded bedding absent so that turbidity currents do not seem to have been important agents of transportation. The best explanation of most features of the sediments seems to be one involving glaciation and iceberg transportation. The exception to these remarks are the Rathbones and Parramore Formations which combine relative mineralogical maturity with good sorting, lack of erratics, cross-bedding ripple marking, slump structure and intraformational conglomerates. Except for the high degree of angularity of their grains they are normal members of the ortho-quartzite-limestone suite. It has been suggested earlier that they were produced mainly by reworking of earlier Permian sediments.

One feature of special interest is the development of a mosaic texture in several of the sandstones, e.g., Rathbones, Jarvis, "Woodbridge" and Risdon Formations, by the regrowth of quartz so that the quartz grains often have sutured contacts. This produces a texture similar to that of contact metamorphic hornfelses, but in this section there is at least 140 feet of sediment below the Rathbones Formation and 600 feet of sediment above the Risdon with no dolerite and the nearest dolerite laterally is over half a mile away. Because of this the mosaic texture is regarded as a product of normal lithification rather than contact metamorphism.

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LOCALITY INDEX

	Latitude	Longitude
Avoca	41° 47′	147° 43′
Bothwell	42° 23′	147° 01′
Coles Bay	42° 07′	148° 19′
Cressy	41° 01′	147° 05′
Deloraine	41° 31′	146° 40′
Eaglehawk Neck	43° 01′	147° 55′
Fingal	41° 36′	147° 53′
Florentine Valley	42° 35′	146° 30′
Gormanston	42° 04′	145° 35′
Hobart	42° 52′	147° 20′
Maria Island	42° 37′	148° 06′
Marlborough	42° 11′	146° 30′
Mt. La Perouse	43° 29′	146° 45′
St. Marys	41° 35′	148° 12′
Seymour	41° 45′	148° 16′
Snug	43° 04′	147° 15′
Snug Falls River	43° 04′	147° 15′
Woody Island	43° 19′	147° 13′

The following localities are all close to Hobart so that their co-ordinates are given in terms of the state grid system. Co-ordinates are given as thousands of yards east and north of the origin of that grid system.

	East	North
Altamont	502·6	735·6
Black Snake Gully, Quarries, Granton	509·1	735·3
Berriedale Quarry	508·5	727·4
Bundella Station	503·1	736·8
Byers Creek	506·3	737·5
Cascades	515·4	719
Fergusson Creek	504·3	735·5
Ferntree	512·6	715·9
Geiss Creek	504·7	736·6
Grange Quarry	521·05	714·67
Huon Road	513·5	717·6
Jarvis Creek	504·0	736·3
Mt. Dromedary	500·0	741·5
Mt. Faulkner	506·6	731·3
Mt. Nassau	506·0	733·4
New Town Creek	511·3	720·7
Parramore Creek	505·2	736·8
Porter Hill	521·5	715·5
Rathbone's Quarries, Mt. Nassau	506·3	736·8
Rayner Creek	505·8	737·3
Risdon	519·4	719·2
Sandy Bay	521·5	715·5
Weily's Quarry, Glenorchy	512·3	724·4

SOME TASMANIAN HARVESTMEN OF THE SUB-ORDER PALPATORES

By

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(With 40 Text Figures)

ABSTRACT

Three new species belonging to the little-known family Acropsopilionidae are described. Two of them are placed in a new genus *Tasmanopilio* and the third in the genus *Austropsopilio* Forster. A key to the genera is provided. An account of four species belonging to the family Phalangiidae is also given. One of the species, *Spinicrus tasmanicum* (Hogg), is the only member of the sub-order Palpatores hitherto recorded from Tasmania. Two of the other species are new and also belong to the genus *Spinicrus* Forster. The remaining species is the widely distributed European phalangiid, *Opilio parietinus* (De Geer), which is often seen on buildings in Hobart and Launceston during summer.

INTRODUCTION

Little has been written on Tasmanian harvestmen belonging to the sub-order Palpatores. The members of the sub-order are readily recognized by the following features:—

(1) The sternum of the cephalothorax is short and transverse.
(2) The tarsi of the legs are provided each with a single simple claw.
(3) The pedipalpi are slender and cylindrical.
(4) The openings of the scent glands are situated on the lateral margins of the carapace and are not elevated on a protuberance.

Many species have very long slender legs and are sometimes mistaken for spiders. However, they are readily distinguished from spiders by the fact that the abdomen is not separated from the cephalothorax by a slender pedicel and also by the fact that they do not possess silk glands and therefore are unable to spin.

The only member of the sub-order previously recorded from Tasmania is *Spinicrus tasmanicum* (Hogg), which was described in 1909 under the name *Pantopsalis tasmanica*. The description was based on three dry and mutilated specimens in the British Museum. Some years later the species was again described by Dr. Roewer (1912, p. 277), who had received further specimens from Tasmania. In the present paper some additional information on the harvestman is given. Two new species belonging to the same genus are also described.

Opilio parietinus (De Geer), which is a very common species in Europe, has apparently been introduced into Tasmania and has become quite numerous in many parts of the State. At present it seems to be confined to the settled and cultivated areas.

Of particular interest is the discovery in Tasmania of three representatives of the little-known family Acropsopilionidae. Up to the present only about six species have been recorded for the whole world. However, the family has a wide distribution. One species occurs in Chile, three in South Africa, one in New Zealand and one in Queensland. The members of the family are small, usually being not more than three or four millimeters in length. They occur in moss, grass, leaf-mould, forest debris, &c. Of the three new Tasmanian species, two have been placed in a new genus, *Tasmanopilio*, and the third in the genus *Austropsopilio*, which Dr. Forster erected for the Queensland species. A key to the genera and descriptions of the Tasmanian species are given in the following pages.

Sub-order PALPATORES Thorell

Family ACROPSOPILIONIDAE Roewer

Genus **TASMANOPILIO** gen. n.

Eyemound large but not elongated, divided into two ocular lobes by a deep groove, which ends in a V-shaped notch in front. Eyes large and surrounded by black rims. Carapace divided into two segments by a transverse groove. Three abdominal tergites free, the others fused. Dorsal surface of body smooth and devoid of tubercles and spines. Pedipalpi with multisetose lobes or multisetose spines on all segments except coxa and tarsus. The metatarsi without a calcaneus. Tarsal segmentation: 7-10, 9-13, 9-10, 10. Tarsal claws simple.

Genotype: *Tasmanopilio fuscus* sp. n.
Type Locality: Mount Wellington, Tasmania.

The genera already placed in the family Acropsopilionidae are *Acropsopilio* Silvestri from Chile, *Cadella* Hirst from South Africa, *Zeopsopilio* Forster from New Zealand and *Austropsopilio* Forster from Queensland. The new genus *Tasmanopilio* may be distinguished from them by the characters given in the following key:—

KEY TO GENERA OF THE FAMILY ACROPSOPILIONIDAE

1. Eyemound elongated .... *Austropsopilio* Forster
   Eyemound not elongated 2
2. Tarsus of pedipalpus with spines 3
   Tarsus of pedipalpus without spines 4
3. Abdomen with segmental grooves .... *Acropsopilio* Silvestri
   Abdomen without segmental grooves .... *Zeopsopilio* Forster
4. Tibia of pedipalpus with setose lobes .... *Tasmanopilio* gen. n.
   Tibia of pedipalpus without setose lobes .... *Cadella* Hirst

TASMANOPILIO FUSCUS sp. n.

(Figures 1-7)

Holotype Male

Measurements in millimetres: Body-length 1·19, length of carapace 0·51.

	Cox.	Troch.	Fem.	Pat.	Tib.	Met.	Tars.	Total
Leg 1	0·27	0·12	0·48	0·27	0·29	0·41	0·52	2·36
Leg 2	0·34	0·12	0·62	0·34	0·52	0·60	0·85	3·39
Leg 3	0·33	0·11	0·40	0·26	0·34	0·56	0·57	2·57
Leg 4	0·41	0·12	0·66	0·30	0·45	0·82	0·64	3·40
Pedipalp	0·16	0·15	0·37	0·27	0·22	....	0·15	1·32

Colour (in alcohol): Dorsal surface of body dark-brown, pale between the ocular lobes. Legs dark-brown except the bases of the femora, which are nearly white. Pedipalpi and ventral surface of body pale-brown. Chelicerae dark-brown, black at apex.

Eyemound large, smooth, rounded and projecting slightly over the anterior margin of carapace. Eyes large and surrounded by black rims. A deep groove, which ends in a V-shaped notch in front, divides the eyemound into two ocular lobes. The base of the eyemound, at its junction with the carapace, is surrounded by a narrow groove. The dorsal surface of the body is smooth and clothed with a few short scattered hairs. A strongly recurved furrow bounded in front by a ridge separates the carapace from the tergal region. A short distance in front of the recurved furrow is a transverse groove ending on each side near the apertures of the scent glands and dividing the carapace into two segments. The five anterior tergites are fused but the three posterior ones are free. The fused tergal part is divided into three regions by two shallow transverse grooves. Each of the two anterior regions has a small median oval sclerite and is probably composed of two fused tergites, the segmental groove between them having been obliterated.

The genital operculum is large and pointed in front. Its anterior extremity lies between the first coxal lobes. The surface of the operculum is clothed with a few short setae. The penis (fig. 3) is armed ventrally with a long black strongly chitinized curved spine, opposite the centre of which is a short stout bifid tooth. The curved spine is directed forwards and its apex lies between two lobes, each of which bears five coarse black setae. The glans penis projects anteriorly from between the lobes.

The coxae are clothed with a few scattered setae but are devoid of spines and tubercles. The coxal lobes are widely separated and those of the first pair are flat and immovable. The free sternites are separated by grooves. Each has a transverse row of setae, about four on each side. The anal operculum is a small crescent-shaped plate. A corona analis is absent.

Chelicerae small and unarmed. Basal segment measures about 0·18 mm. long and the second segment 0·44 mm. The pedipalpi are slightly longer than the body. All the segments are clothed with a few short black setae. The trochanter has a large multisetose spine below. The femur is provided with a dorsal row of four small tubercles, a rounded multisetose lobe near the apex on the prolateral side, a large unisetose spine on the retrolateral side and a large multisetose basal spine ventrally. The patella has a small rounded multisetose lobe at the apex on the prolateral side and the tibia has a large multisetose lobe on the retrolateral side. The tarsus is short and provided with coarse setae below. It ends in a simple claw.

The legs are clothed with a dorsal, a prolateral, a retrolateral and a ventral row of black setae on femora, patellae, tibiae and metatarsi. The tarsi are clothed with fine hairs and a few setae. Fine hairs are also present on the ventral surface of the metatarsi. Each metatarsus has a small proximo-dorsal tubercle. Tarsal segmentation: 10, 13, 10, 10. The distal segments of the tarsus are somewhat moniliform. The tarsal claw is simple.

Allotype Female

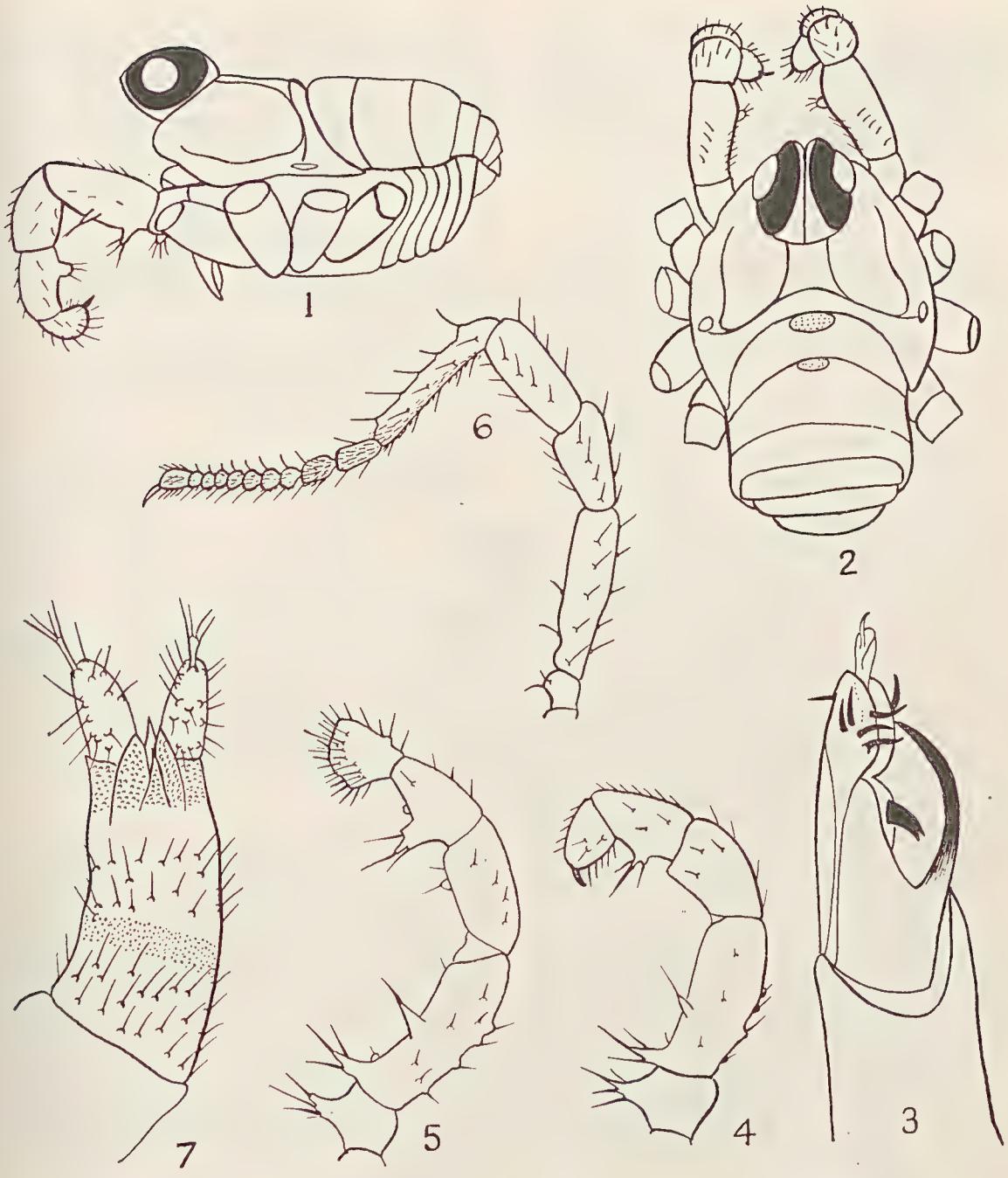
Measurements in millimeters: Body-length 1·26, length of carapace 0·51.

	Cox.	Troch.	Fem.	Pat.	Tib.	Met.	Tars.	Total
Leg 1	0·23	0·11	0·34	0·17	0·23	0·34	0·46	1·88
Leg 2	0·31	0·14	0·51	0·29	0·40	0·51	0·83	2·99
Leg 3	0·29	0·11	0·34	0·23	0·29	0·40	0·46	2·12
Leg 4	0·40	0·11	0·57	0·29	0·40	0·65	0·60	3·02
Pedipalp	0·17	0·14	0·34	0·29	0·17	....	0·17	1·28

The female resembles the male in colour and general appearance but differs in the tarsus of the pedipalpus being more rounded, more densely clothed with setae and without a claw. The tibia has a rounded multisetose lobe on the prolateral as well as on the retrolateral side, and the femur has a large spine as well as a multisetose lobe on the prolateral side.

The legs are slightly shorter than those of the male and the first femur has two small ventral tubercles. The tarsal formula 7, 9, 9, 10 also differs from that of the male.

The ovipositor (fig. 7) measures about 0·82 mm. when extended. The distal part is cleft into two unsegmented lateral finger-like lobes, each of which is clothed with a number of setae and bears at its apex a small brush-like sensilla. Between the bases of the two lobes and surrounding the aperture of the vagina are four dark pointed lobules. A single dark band surrounds the trunk of the ovipositor.



Tasmanop'l o fuscus gen. et sp. n.

FIG. 1.—Lateral view of body of male.
FIG. 2.—Dorsal view of body of male.
FIG. 3.—Lateral view of distal end of penis.
FIG. 4.—Retrolateral view of pedipalpus of male.
FIG. 5.—Retrolateral view of pedipalpus of female.
FIG. 6.—Leg of male.
FIG. 7.—Ovipositor.

Locality: Mount Wellington, Tasmania, 14th June, 1944. The harvestman occurs among fallen leaves under dense shrubs such as *Richae scoparia* on the summit of the mountain (4166 ft.). It is also found at lower levels amongst the moss which covers large rocks, but has not been collected below about 2400 ft. Adult specimens are found during the winter months May-July, juvenile specimens during January and December.

TASMANOPILIO MEGALOPS sp. n.

(Figures 8-13)

Holotype Female

Measurements in millimeters: Body-length 0·97, length of carapace 0·40.

	Cox.	Troch.	Fem.	Pat.	Tib.	Met.	Tars.	Total
Leg 1	0·20	0·07	0·26	0·19	0·19	0·26	0·37	1·54
Leg 2	0·27	0·08	0·41	0·23	0·31	0·39	0·56	2·25
Leg 3	0·22	0·08	0·27	0·22	0·22	0·34	0·49	1·84
Leg 4	0·27	0·10	0·45	0·25	0·35	0·56	0·57	2·55
Pedipalp	0·14	0·12	0·34	0·27	0·18	....	0·16	1·21

Colour (in alcohol) : Dorsal surface of body brown, pale between ocular lobes. Appendages brown. Ventral surface light-brown. Genital operculum with a dark area on each side.

Eyemound (figs. 8-9) large and wide, occupying the full width of the carapace in front. It is not elongated but projects slightly over the anterior margin. A deep median furrow divides the eyemound into two ocular lobes and ends in a V-shaped notch in front. The eyes are large and surrounded by black rims. A narrow groove surrounds the base of the eyemound. The carapace is separated from the tergal region by a well marked recurved furrow. Between the base of the eyemound and the recurved furrow is a transverse groove ending on each side near the aperture of the scent gland, and dividing the carapace into two segments. The five anterior tergites are fused and the three posterior ones free. The fused tergal area is divided into three regions by two shallow transverse grooves. Each of the two anterior regions has a small oval median sclerite. The carapace and tergites are devoid of tubercles and spines. The integument, however, is clothed with minute spinules or microtrichia, which are difficult to see except at high magnification.

The genital operculum (fig. 10) is large and pointed in front. Its anterior extremity lies between the first coxal lobes and its surface is clothed with a few scattered setae. The coxal lobes are wide apart and those of the second pair bear two small tubercles. The coxae are clothed with a few setae. The fourth pair have on the ventral surface in the basal half two conspicuous tubercles close together one behind the other. A small projection is present on the retrolateral margin of the coxa and opposite the respiratory spiracle. The free sternites are separated by grooves and each has a transverse row of short setae. A corona analis is absent.

The chelicerae small and unarmed. The pedipalpi (figs. 11-12) are provided with multisetose lobes and spines as described in the case of the female of the preceding species, *Tasmanopilio fuscus*.

The legs also resemble those of *T. fuscus* but in addition to possessing a small proximodorsal tubercle on each metatarsus, they also have a similar dorsal tubercle on the apical half of each patella. Tarsal segmentation: 7, 9, 9, 9.

Locality: Liffey Falls, Tasmania, 14th May, 1953. The holotype and three other adult females were found amongst moss and fallen leaves in *Notofagus* forest. Three immature specimens were collected from moss at the same locality, 22nd January. 1953.

Tasmanopilio megalops differs from *Tasmanopilio fuscus* in having a relatively much larger and wider eyemound, two conspicuous tubercles below the fourth coxae, a dorsal tubercle on each patella and a tarsal formula: 7, 9, 9, 9.

Genus **AUSTROPSOPILIO** Forster, 1955

AUSTROPSOPILIO CYGNEUS sp. n.

(Figures 14-17)

Holotype Female

Measurements in millimeters: Body-length (including the eyemound) 2·11, length of carapace 0·86.

	Cox.	Troch.	Fem.	Pat.	Tib.	Met.	Tars.	Total
Leg 1	0·40	0·17	0·57	0·29	0·40	0·51	0·63	2·97
Leg 2	0·51	0·23	0·86	0·40	0·69	0·86	0·86	4·41
Leg 3	0·40	0·23	0·57	0·29	0·51	0·63	0·69	3·32
Leg 4	0·63	0·29	0·86	0·46	0·63	1·03	0·97	4·87
Pedipalp	0·29	0·29	0·63	0·40	0·29	....	0·23	2·13

Colour (in alcohol): Carapace and eyemound yellowish-brown, the rest of the dorsal surface mainly dark-brown. Legs yellowish-brown with dark-brown tarsi and dark-brown bands on femora and metatarsi. Pedipalpi and chelicerae brown. Movable and fixed fingers of chelicerae black at apex. Ventral surface of body light yellowish-brown with the genital operculum darker. The multisetose spines and lobes on the pedipalpi have black tips.

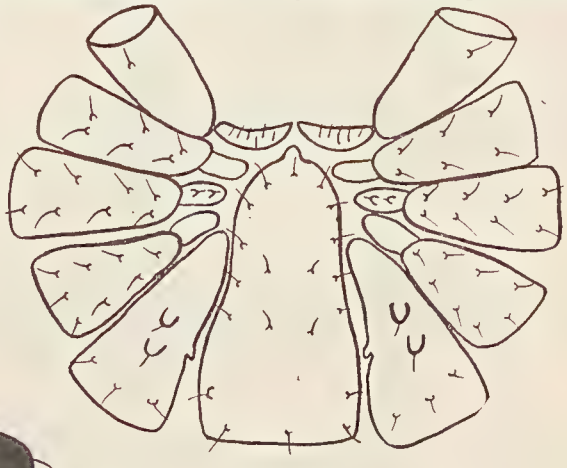
Eyemound long, projecting over the front of the carapace and divided distally by a V-shaped notch into two conical lobes directed forwards (fig. 14). The eyes are large and surrounded by black rims. They are separated from each other by a deep groove which extends forwards to the V-shaped notch. The dorsal surface of the eyemound is furnished with small rounded tubercles, each of which carries a forwardly directed seta. The base of the eyemound, at its junction with the carapace, is surrounded by a narrow groove. On each side of the carapace and extending postero-laterally from the base of the eyemound to near the apertures of the scent glands is a ridge furnished with a row of tubercles. The posterior margin of the carapace is marked by a strongly recurved groove bounded in front by a ridge with a row of tubercles. The region on each side of the eyemound is without tubercles.

The five anterior abdominal tergites appear to be fused and the posterior three free. All are provided with setose tubercles (fig. 15). The fused tergal part is divided into three regions by two transverse grooves. The arrangement of the tubercles suggests that the first region represents tergal seg-

ments I and II, the second III and IV and the third V. Each free sternite is furnished with a transverse row of tubercles, four on each side. The genital operculum is large and extends forwards to the first coxal lobes. Its surface is provided with about 18 small tubercles, six of which form a recurved row immediately behind the anterior margin. The coxal lobes are widely separated. Those of the second coxae each bear two small tubercles.

The chelicerae are short and unarmed. The pedipalpi (fig. 16) are about equal in length to the body. The trochanter has a large multisetose spine below.

8



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Tasmanopilio megalops gen. et sp. n.

FIG. 8.—Dorsal view of body of female.
FIG. 9.—Lateral view of carapace and eyemound.
FIG. 10.—Ventral view of genital operculum and coxae.
FIG. 11.—Prolateral view of pedipalpus of female.
FIG. 12.—Retrolateral view of pedipalpus of female.
FIG. 13.—Leg I of female.

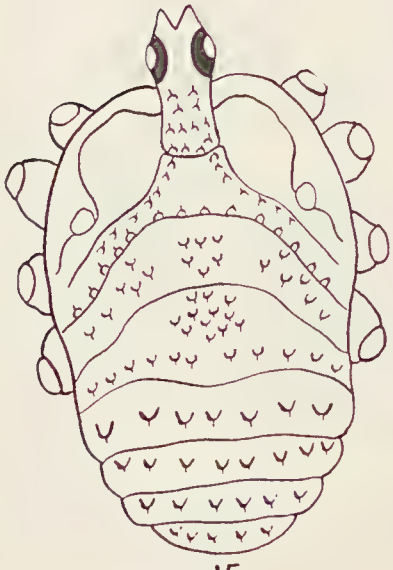
The femur, patella and tibia are provided with a longitudinal row of conical tubercles on ventral, dorsal, prolateral and retrolateral sides. Below the femur is a large multisetose basal spine, two spines on the outer side, and one spine and a blunt apical multisetose lobe on the inner side. Below the patella on the outer side are two spines and on the inner side a large spine and blunt multisetose spine or lobe. Below the tibia is a stout multisetose lobe on the outer side and a smaller multisetose tooth on the inner side. Tarsus is short with a rounded apex densely clothed with setae.

Legs slender, the fourth pair being the longest and slightly more than twice the length of the body. A longitudinal row of conical setose tubercles on dorsal, prolateral, retrolateral and ventral surfaces of each patella and tibia. Each femur has a longitudinal dorsal row of conical tubercles, which increase in size distally. At the apex of the femur there are two tubercles on each side. The first leg (fig. 17) has a large spine below the trochanter, and two large and two small spines below the femur. Tarsal segmentation: 9, 13, 10, 11. Each tarsus ends in a simple claw. All the metatarsi have a rounded proximodorsal tubercle. Calcaneus absent.

Locality: Liffey Falls, Tasmania, 23rd February, 1929. The holotype was found among fallen leaves

14

17



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16

Austropsopilio cygneus sp. n.

FIG. 14.—Lateral view of body of female.
FIG. 15.—Dorsal view of body of female.
FIG. 16.—Retrolateral view of pedipalpus of female.
FIG. 17.—Leg I of female.

under *Notofagus* trees. A second immature specimen was collected from moss at the same locality, 9th February, 1947.

The species shows a close relationship to *Austropsopilio novaehollandiae* Forster from Queensland, especially in the form of the pedipalpi. However, it differs from that species in possessing tubercles on the elongated eyemound, in the armature of the legs and in the segmentation of the tarsi.

Family PHALANGIIDAE Simon

Genus **OPILIO** Herbst

Eyemound rounded. Interocular furrow denticulate. The eyemound is removed from the front margin by a distance equal to 1-2 times its diameter. The surface of the carapace in front of and at the sides of the eyemound provided with small denticles. Thoracic and abdominal tergites each with a transverse row of denticles. Chelicerae and pedipalpi of similar form in both sexes. Patella and tibia of pedipalp without apophyses. Legs long and slender. Sexual dimorphism very slight.

Genotype: *Phalangium parietinum* De Geer.

Locality: Europe.

OPILIO PARIETINUS (De Geer)

(Figs. 18-22)

This harvestman is a common European species, which has probably been introduced into Tasmania by the agency of shipping. The species also occurs in Asia and North America.

Male

Measurements in millimeters: Body-length 6·72, length of carapace 1·54.

	Cox.	Troch.	Fem.	Pat.	Tib.	Met.	Tars.	Total
Leg 1	2·31	0·63	7·00	1·75	4·90	6·37	10·50	33·46
Leg 2	2·17	0·77	11·20	2·10	9·17	8·33	24·00	57·74
Leg 3	2·45	0·56	6·09	1·61	4·69	6·65	10·00	32·05
Leg 4	3·22	0·77	7·70	1·75	5·95	9·66	9·76	38·81
Pedipalp	0·29	0·40	1·26	0·80	0·86	....	2·00	5·61

Colour (in alcohol): Carapace and abdomen cream, speckled and blotched with white, yellow and brown. Abdomen without a saddle-shaped area or median stripe. Chelicerae and pedipalpi cream spotted with brown. Legs mainly dark-brown with some yellowish spots. Coxae pale with elongated dark-brown spots on ventral surface. Sternites with a few dark-brown spots arranged in transverse rows.

Carapace provided with small denticles as shown in fig. 18. Eyemound set back from front margin by a distance equal to its diameter and furnished with a longitudinal row of about six denticles above each eye. The thoracic and abdominal tergites each provided with a transverse row of denticles. Segmental grooves on abdomen shallow.

Chelicerae small. The first segment measures 1·20 mm. and the second 2·23 mm. long. A few small denticles are present above the distal half of the first segment and the proximal quarter of the second. The sectorial margin of the movable finger has a large conical tooth near the middle and that of the fixed finger a slightly smaller tooth nearer the base. Both sectorial margins have serrations on the distal half.

Pedipalpi (fig. 19) short and small. Femur, patella and tibia furnished with denticles and short setae. Tarsus clothed with short setae and fine hairs but devoid of denticles. The tarsal claw is non-pectinate.

Legs long and slender. An erect spine-like process above the distal end of coxae I-III. Small denticles are present on all trochanters, femora, patellae, tibiae, metatarsi and some tarsal segments. Metatarsi I-IV have 2, 3, 2, 3 pseudosegments respectively. Tarsi I-IV have 35, 79, 37, 37 segments respectively.

The form of the penis is shown in fig. 20. The glans ends in a curved spine-like point. At the distal end of the trunk of the penis there is a pair of oval concave plates, which are situated on the dorsal side immediately behind the base of the glans.

Female

Measurements in millimeters: Body-length 6·0, length of carapace 1·54.

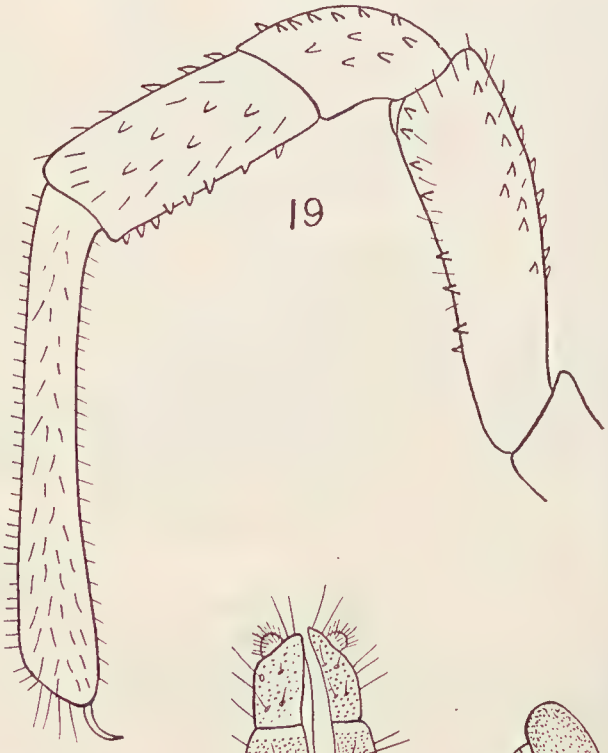
	Cox.	Troch.	Fem.	Pat.	Tib.	Met.	Tars.	Total
Leg 1	1·43	0·40	4·00	1·26	3·14	3·71	7·20	21·14
Leg 2	1·54	0·46	7·54	1·71	6·17	4·91	15·88	38·21
Leg 3	1·71	0·51	4·00	1·26	3·14	4·34	7·14	22·10
Leg 4	2·11	0·46	6·06	1·43	4·40	6·11	10·17	30·74
Pedipalp	0·23	0·29	1·14	0·54	0·63	....	1·54	4·37

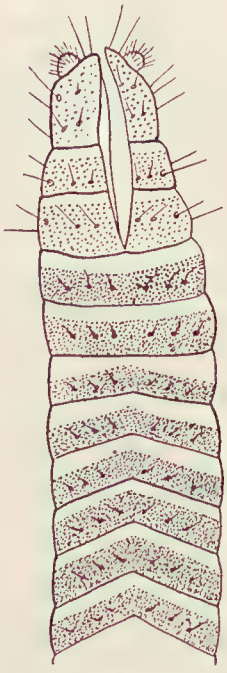
The female closely resembles the male in colour, markings and general appearance. The carapace, eyemound and tergites are denticulate as in the male.

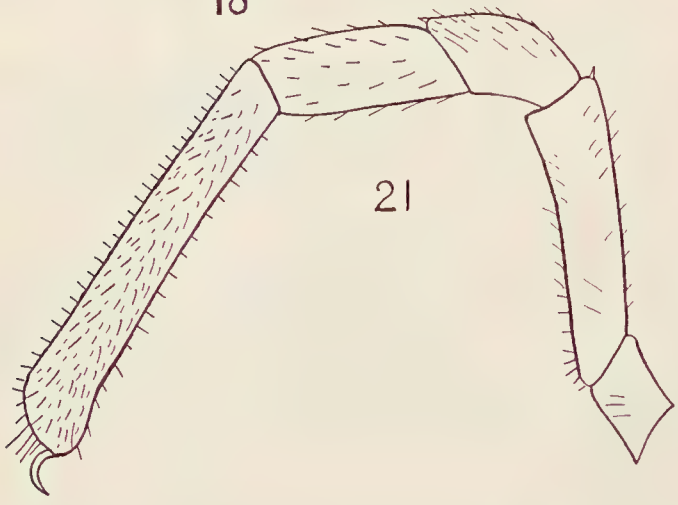
The chelicerae and pedipalpi (fig. 21), however, are smooth and devoid of denticles. The legs are shorter than those of the male and denticles are present on only the trochanters and the femora. Metatarsi I-IV have 2, 3, 2, 3 pseudosegments respectively. Tarsi I-IV have 34, 72, 37, 37 segments respectively.

The ovipositor (fig. 22) is long and composed of about 34 dark-brown segments. The two distal segments are cylindrical the remainder somewhat angular. Each segment is encircled by about 12 setae. The distal end of the ovipositor is divided into two finger-like lobes, each composed of three segments and having an oviducal furrow on the inner surface. On the outer side near the apex each lobe bears a hemispherical, setose sensory organ.

Localities: This introduced harvestman is common in both Hobart and Launceston. During summer it may often be seen with its long slender legs spread out radially round its body resting on the shady side of houses and other buildings. Up to the present it has been found only in settled areas and does seem to have penetrated into the bush.







Opilio parietinus (De Geer).

FIG. 18.—Dorsal view of body of male.
FIG. 19.—Retrolateral view of pedipalpus of male.
FIG. 20.—Distal end of penis.
FIG. 21.—Retrolateral view of pedipalpus of female.
FIG. 22.—Distal end of ovipositor.

Genus SPINICRUS Forster, 1949

This genus was established by Forster (1949, p. 63) in order to separate Australian from New Zealand species of *Pantopsalis*, the claw of the pedipalp being pectinate in the Australian forms and non-pectinate in the New Zealand forms.

The genus may be defined as follows: Eyemound rounded, with a slight interocular groove, and situated little more than once its transverse diameter from the anterior margin of the carapace. In the males the carapace is usually (but not always) provided with denticles or spicules. In the females it is smooth. The abdomen is smooth in both sexes and the segmental grooves shallow. Chelicerae of males at least twice the length of the body and furnished with numerous denticles. Chelicerae of females short and smooth. Pedipalpi in both sexes smooth, slender and without apophyses. Claw of pedipalpi pectinate. Legs very long and thin. Tibia II with pseudosegmentation.

Genotype: *Pantopsalis tasmanica* Hogg, 1910.

Type Locality: Tasmania.

Three species belonging to the genus *Spinicrus* have been recorded from the mainland of Australia and one from Tasmania. Two new forms are described in the present paper. The species are readily distinguished by the features of the males as indicated in the following key.

KEY TO MALES OF SPECIES IN THE GENUS *SPINICRUS*.

1. Carapace with two humps ..... *S. camelus* Forster
   Carapace without humps 2
2. Eyemound armed with denticles 3
   Eyemound without denticles 4
3. Tibia I with denticles below ..... *S. thrypticum* sp. n.
   Tibia I without denticles ..... *S. stewarti* Forster
4. Femur I without denticles ..... *S. nigricans* sp. n.
   Femur I with denticles 5
5. Trochanter I without spines ..... *S. tasmanicum* (Hogg)
   Trochanter I with two spines ..... *S. continentale* (Roewer)

Of the species mentioned in the foregoing key *S. camelus* occurs in N.S.W., *S. stewarti* and *S. continentale* in Victoria and the others in Tasmania.

SPINICRUS TASMANICUM (Hogg)

(Figures 23-28)

As mentioned above this species was originally described under the name of *Pantopsalis tasmanica* by Hogg (1910, p. 279). The description was based on three dry and mutilated specimens in the British Museum. A revised description based on two males and four females from Hobart was published by Roewer (1912, p. 277). In the following account of the species some additional information is given.

Male

Measurements in millimeters: Body-length 4·85, length of carapace 1·68.

	Cox.	Troch.	Fem.	Pat.	Tib.	Met.	Tars.	Total
Leg 1	1·37	0·40	4·40	1·14	3·83	5·43	7·71	24·28
Leg 2	1·43	0·40	7·19	1·20	7·42	6·63	18·90	43·17
Leg 3	1·37	0·40	3·54	1·14	3·43	5·25	6·80	21·93
Leg 4	1·49	0·57	5·71	1·20	5·30	8·17	9·54	31·98
Pedipalp	0·23	0·34	1·26	0·57	0·69	....	1·71	4·80

Colour (in alcohol): Dorsal surface of body fawn with a median silvery white stripe bordered with brown extending from the eyemound to the posterior end of the abdomen. Eyemound silvery white with a black ring round each eye. A median pair of short brown stripes extends from the eyemound to the front margin. A few dark-brown marks are present on each side of carapace and abdomen. Appendages are fawn. Ventral surface of body pale.

Except for two or three minutes spicules on each side of the anterior margin in front of the eyemound, the carapace and abdomen are smooth. Eyemound low, rounded and smooth, with a very slight interocular groove. It is situated about its diameter from the front margin. Segmental grooves of abdomen distinct.

Chelicerae (fig. 24) very long, the first and second segments each being longer than the body. The first segment decreases slightly in diameter towards the middle of its length and then expands near the apex. The second segment gradually increases in diameter distally and is widest at the base of the movable finger. Both segments are covered with small spinules of uniform size, those on the second segment being more densely arranged than those on the first segment. Moyable and fixed fingers cross near the apex. There is a large black conical tooth near the middle of the sectorial margin of the movable finger and a large blunt, somewhat truncate, tooth in a more basal position on the fixed finger (fig. 25). Distal to these teeth the sectorial margins of both fingers are furnished with fine serrations.

Pedipalpi are short and smooth; clothed with short setae but without spinules. Tarsus longer than other segments. Claw furnished with about eight teeth in basal half (fig. 26).

Coxae I, II, and III with a slender apical spine above the distal end. The spine on coxa I is immediately below the aperture of the scent gland. Legs long and slender. In the resting position the two anterior pairs are extended forwards and the two posterior pairs backwards. With the exception of femur I, which is armed with small denticles, the segments of all the legs are smooth. The denticles on femur I are more numerous on the ventral than on the dorsal surface. Tibia II has 5-7 pseudosegments. The other tibiae show no signs of segmentation. Metatarsi I-IV have 3, 7, 3, 6 segments respectively and tarsi I-IV have 41, 77, 43, 45 segments respectively.

The genital operculum extends forward as far as the bases of coxae I and is slightly indented at the apex. The penis has the form shown in fig. 27. The glans is short and pointed. It is bent dorsally at right angles to the long axis of the main trunk of the penis. Behind the glans and on the ventral side are four tufts of long curved setae. The tufts are situated two on each side, one close behind the other.

Female

Measurements in millimeters: Body-length 6·85, length of carapace 1·78.

	Cox.	Troch.	Fem.	Pat.	Tib.	Met.	Tars.	Total
Leg 1	1·20	0·68	3·60	1·14	3·43	4·63	7·99	22·67
Leg 2	1·31	0·40	6·51	1·26	7·14	6·00	16·23	38·85
Leg 3	1·54	0·40	3·37	1·20	3·08	4·68	6·28	20·55
Leg 4	2·97	0·51	5·76	1·26	5·14	8·28	8·85	32·77
Pedipalp	0·34	0·23	1·20	0·86	0·85	....	1·88	5·36

The female resembles the male in colour and markings. The carapace is smooth and without spicules. The chelicerae small and smooth; the basal segment measures 0·80 mm. and the second segment 1·71 mm. Both segments are without spicules. The pedipalp is slender and unarmed. The legs long and slender. Tibia II has 6-7 pseudosegments. Metatarsi I-IV have 4, 7, 3 (or 4), 6 pseudosegments respectively. Tarsi I-IV have 44, 75, 41, 47 segments respectively.

The ovipostor (fig. 28) has the usual form found in the Phalangiidae. The distal end is divided into two narrow lobes, each of which is composed of three segments and has a longitudinal furrow on the inner surface. On the outer side near the apex of each lobe is a conical sensory organ clothed with short setae. The trunk of the ovipositor is composed of about 25 dark-brown annular segments. The 10 segments immediately behind the distal lobes are each encircled by eight setae. The remaining segments are without setae.

Localities: The species is widely distributed in Tasmania. The collection contains specimens from the Cascades, Risdon, National Park, Tarraleah, Great Lake region, Forth Falls, Wilmot, Fingal, Trevallyn, Bruny Island and elsewhere. Adults may be found during the months October-March. The harvestman occurs in various situations. Specimens have been found under fallen logs and stones, in curled bark on the ground, under the loose bark on Eucalypts and sometimes in low shrubs.

SPINICRUS THRYPTICUM sp. n.

(Figures 29-33)

Holotype Male

Measurements in millimeters: Body-length 4·0, length of carapace 1·43.

	Cox.	Troch.	Fem.	Pat.	Tib.	Met.	Tars.	Total
Leg 1	1·43	0·46	3·14	1·09	2·86	2·17	7·70	18·85
Leg 2	1·40	0·46	5·82	1·14	5·65	1·83	18·30	34·60
Leg 3	1·54	0·34	3·03	1·14	2·63	2·57	7·70	18·95
Leg 4	1·71	0·51	4·57	1·03	4·00	3·71	10·60	26·13
Pedipalp	0·23	0·34	1·14	0·51	0·57	....	1·70	4·49

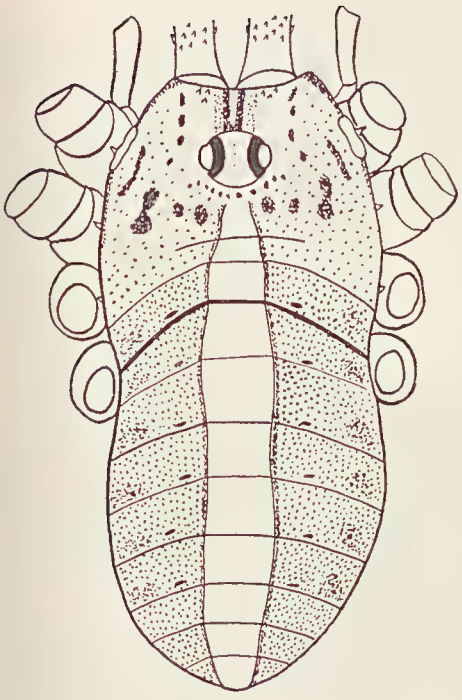
Colour (in alcohol): Carapace light-brown. Margin and lateral angles dark-brown. Eyemound silvery-white between the eyes. Two broken dark-brown lines extend forward from the base of the eyemound to the anterior margin. An irrgular silvery-white patch is present on each side of the eyemound and extends forward to the front margin. Behind the eyemound is a pair of black patches disposed transversely. The anterior two thirds of the dorsal surface of the abdomen has a wide median region, which is brown marked with a few silvery flecks. Behind the brown region is a narrow dark transverse bar followed by a large silvery-white patch bearing a transverse row of brownish dots. On each side the dorsal surface is marked with irregular patches of dark-brown intermingled with silvery flecks. Chelicerae, pedipalpi and legs brown. Femora, tibiae and metatarsi banded with dark-brown. Some silvery-white marks are also present on the legs, especially on the patellae. Two dark patches occur on the intersegmental membrane between coxa and trochanter on the dorsal side of each leg. Ventral surface of body is light-brown with the distal third of each coxa dark-brown. Sternites marked with transverse dark-brown bars bearing silvery-white spots.

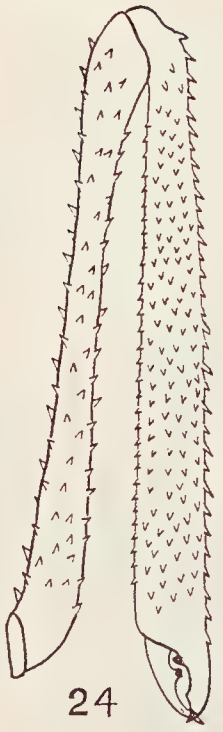
The carapace is furnished with small denticles arranged in six groups, two on each side close behind the front margin and one on each side of the eyemound (fig. 29). In front of and behind the aperture of the scent gland is a small conical projection. The eyemound is set back from the front margin by a distance equal to once its transverse diameter. The interocular furrow is very shallow. Above each eye is a double row of denticles. The abdomen is smooth, but each tergite is furnished with a few short setae.

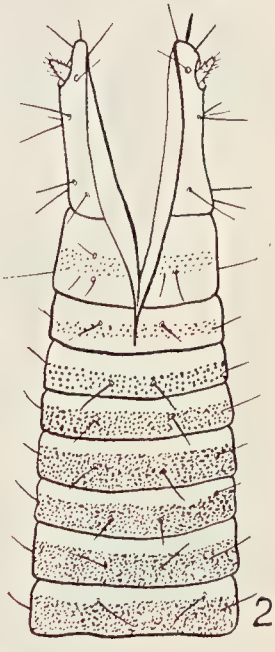
The chelicerae (fig. 30) are more than twice the length of the body. The first segment measures 4·0 mm. and the second 5·4 mm. long. Both segments are densely covered with denticles of uniform size. The movable finger has a large black conical tooth near the middle of its sectorial margin. When the fingers are closed together the tooth fits in between a more basal conical tooth and a truncate serrated projection on the fixed finger (fig. 31).

The pedipalpi are small, slender and smooth. Clothed with short setae but without spines and denticles. The tarsal claw has about six teeth (fig. 32).

The legs are long and slender. On the dorsal side of the distal end of each coxa in the case of legs I-III is a slender erect spine. Trochanters I-IV each with a group of small spines on the anterior surface. Femora I and III are armed with denticles thronughout the full length of the segment, especially on the ventral surface. Femur II has denticles on the proximal two-thirds and femur IV is almost smooth. Patella I and tibia I have a double row of denticles below (fig. 33); other patellae and tibiae are smooth. Tibia II has six pseudosegments on the right and five on the left side; tibia IV has two pseudosegments on both sides. Metatarsi I-IV are short and have 2, 1, 1, 3 pseudosegments respectively. Tarsi I-IV are very long and have 35, 66, 36, 39 segments respectively. Tarsus IV is slender proximally but gradually becomes stouter towards the sixth segment and then thinner towards its distal end.







Spinicrus tasmanicum (Hogg).

FIG. 23.—Dorsal view of body of male.
FIG. 24.—Retrolateral view of chelicera of male.
FIG. 25.—Chela of chelicera.
FIG. 26.—Claw of pedipalpus.
FIG. 27.—Lateral view of distal end of penis.
FIG. 28.—Ovipositor.

Allotype Female

Measurements in millimeters: Body-length 3·88, length of carapace 1·26.

	Cox.	Troch.	Fem.	Pat.	Tib.	Met.	Tars.	Total
Leg 1	1·43	0·46	2·34	1·08	2·28	1·54	6·40	15·53
Leg 2	1·43	0·40	4·74	1·08	4·85	1·43	15·70	29·63
Leg 3	1·31	0·40	2·28	0·97	2·28	1·94	6·30	15·48
Leg 4	1·71	0·46	3·83	1·14	3·43	3·14	8·00	21·71
Pedipalp	0·17	0·23	1·14	0·51	0·68	....	1·50	4·23

Colour (in alcohol): Carapace cream with dark-brown lateral angles and dark-brown spots at each side of the eyemound. Dorsal surface of abdomen with a broad median dark-brown area on the anterior two-thirds. On each side of and immediately behind the dark-brown area the dorsum is silvery-white merging into cream. The last three or four tergites are mainly brown. Basal segment of chelicera silvery-white with brown

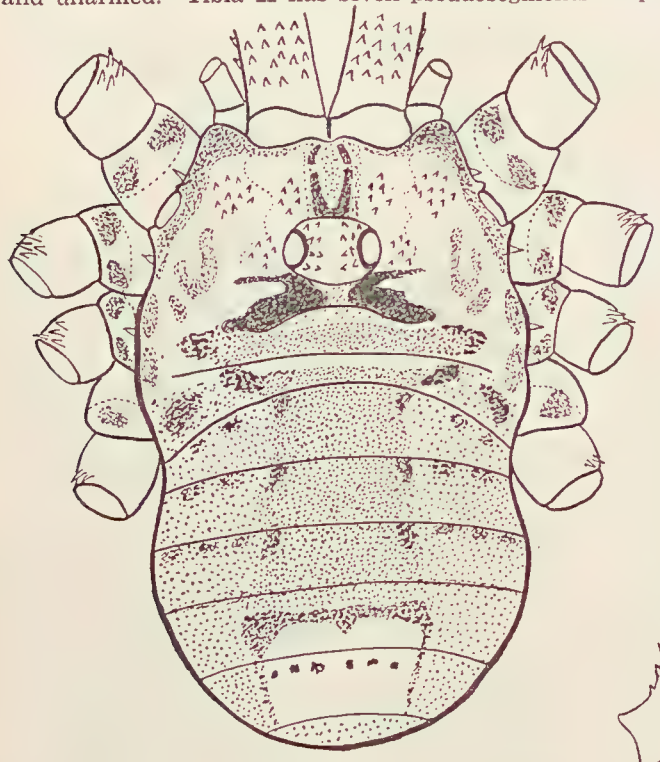
spots; second segment white with brown sides. Coxae yellowish with a dark-brown band at the distal end. Other leg segments as in male.

Carapace and eyemound smooth, otherwise as in male.

Chelicerae small and smooth. The first segment measures 0·74 mm. and the second segment 1·66 mm. long. Pedipalpi as in the male.

Legs long and slender. All segments are smooth and unarmed. Tibia II has seven pseudosegments and tibia IV two. The metatarsi I-IV have 2, 1, 2, 3 pseudosegments respectively. Tarsi I-IV have 36, 66, 35, 39 segments respectively. Tarsus IV is slender and not swollen as in the male.

Localities: The holotype was found by J. L. Hickman near St. Columba Falls at Pyengana, Tasmania, 17th April, 1954, and the allotype in the neighbouring district of Weldborough, 16th April, 1954.



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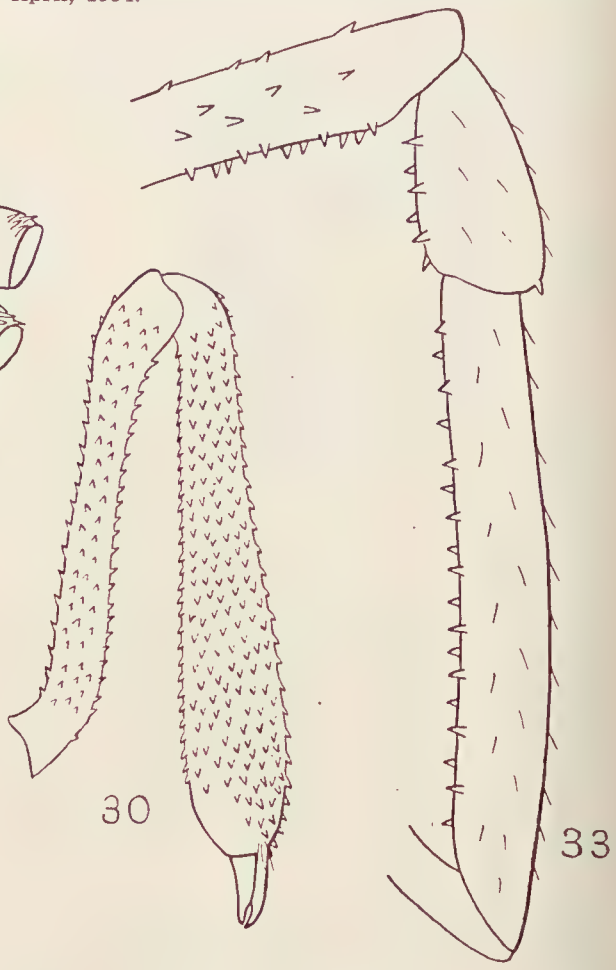

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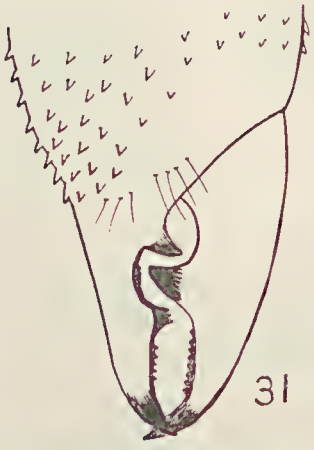

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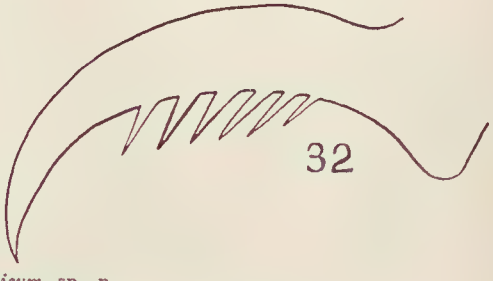

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Spinicrus thrypticum sp. n.

FIG. 29.—Dorsal view of body of male.
FIG. 30.—Retrolateral view of chelicera of male.
FIG. 31.—Chela of chelicera.
FIG. 32.—Claw of pedipalpus.
FIG. 33.—Patella and tibia of leg I of male.

SPINICRUS NIGRICANS sp. n.

(Figures 34-40)

Holotype Male

Measurements in millimeters: Body-length 2·4, length of carapace 0·84.

	Cox.	Troch.	Fem.	Pat.	Tib.	Met.	Tars.	Total
Leg 1	0·86	0·28	4·05	1·03	3·71	2·17	10·51	22·61
Leg 2	0·86	0·29	6·97	0·97	7·14	1·49	24·54	42·26
Leg 3	0·91	0·34	3·43	0·86	3·54	2·23	11·13	22·44
Leg 4	1·14	0·40	5·48	0·97	5·43	2·57	15·60	31·59
Pedipalp	0·23	0·29	2·17	1·03	0·86	....	2·28	6·86

Colour (in alcohol): Carapace light-brown with dark-brown margin and dark-brown marks on each side. A silvery-white patch on each side of the eyemound extends forward to the front margin. Abdomen with a large dorsal dark-brown median region and silvery-white patches on each side. Chelicerae dark-brown; paler at the sides of the first segment and in the mid-dorsal region and distal end of the second segment. Pedipalpi, legs and ventral surface of body brown with a pale median stripe extending from mouth to anus.

Carapace and abdomen soft and smooth. Denticles and spicules absent. Eyemound smooth and without spicules; situated about its diameter from the front margin. Interocular groove shallow and furnished with a few short setae.

Chelicerae long and spinous. The first segment measures 2·17 mm. in length and is shorter and thinner than the second segment, which measures 3·14 mm. long. Both segments are armed with spines and denticles. The first segment has about five large erect spines on the dorsal side in the basal half and a larger number of smaller spines on the ventral surface. The second segment is armed with numerous large curved spines on the dorsal surface (or front). The lateral spines are shorter and on the retrolateral surface some of them form a longitudinal row (fig. 35). The movable finger is almost straight and has a large black conical tooth near the middle of the sectorial margin. The fixed finger has a low serrated projection in the basal half. Both fingers have fine serrations on the distal half of the sectorial margins (fig. 36).

Pedipalpi slender and unarmed. Tarsus is longer than the other segments and its claw is furnished with about eight fine teeth (fig. 37).

Legs very long and slender. The femora and all other segments except coxae I-III are smooth and quite devoid of denticles and spines. Coxae I-III each have a slender erect spinous process on the dorsal side of the distal end. Tibia II has eight pseudosegments. The other tibiae show no signs of segmentation. The metatarsi are very short and each has two pseudosegments. Tarsi I-IV are very long and have 36, 78, 34, 36 segments respectively.

The genital operculum extends forward to the bases of the first coxae. The penis has the form shown in figs. 38-39. It resembles that of *Spinicrus tasmanicum*. The glans is short and bent dorsally. Behind the glans and on the ventral side are four tufts of long curved setae. The tufts are situated two on each side, one close behind the other.

Allotype Female

Measurements in millimeters: Body-length 4·17, length of carapace 1·07.

	Cox.	Troch.	Fem.	Pat.	Tib.	Met.	Tars.	Total
Leg 1	0·91	0·28	4·00	0·91	3·77	2·57	14·05	26·49
Leg 2	0·97	0·28	6·96	0·97	7·71	1·37	27·20	45·46
Leg 3	1·14	0·34	3·71	0·86	3·71	2·86	11·43	24·05
Leg 4	1·19	0·34	5·42	0·91	5·65	2·80	15·70	32·01
Pedipalp	0·17	0·17	1·14	0·68	0·63	....	1·43	4·22

Colour (in alcohol): Carapace yellowish-brown with dark-brown margin and a pair of dark lines in front of eyemound. Dorsal surface of abdomen with a median light coloured stripe. On either side of the stripe the segments are dark-brown with silvery-white markings in the transverse grooves. There is also a large silvery-white patch on each side immediately behind the carapace. Legs and pedipalpi yellowish-brown banded with dark-brown. Coxae dark-brown on distal third.

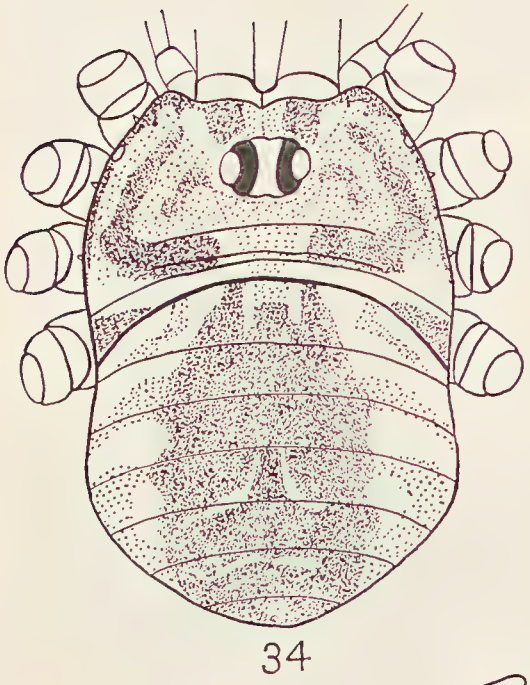
Carapace, eyemound and abdomen smooth.

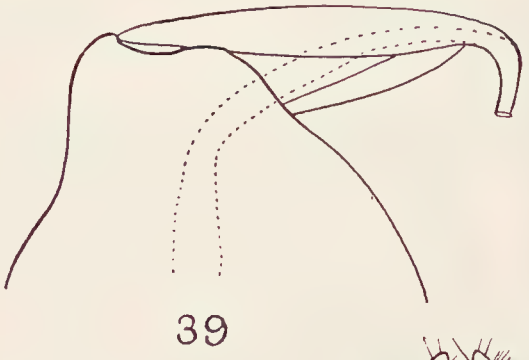
Chelicerae unarmed and much smaller than those of the male. The first segment measures 0·63 mm. and the second 1·37 mm. long.

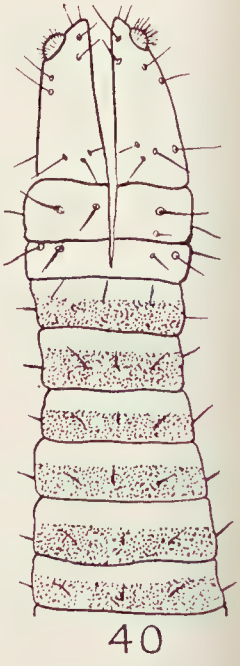
Pedipalpi and legs resemble those of the male. Tibia II has six pseudosegments on the right and eight on the left side of the body. Metatarsi are short and each has two pseudosegments. Tarsi I-IV have 40, 93, 38, 44 segments respectively.

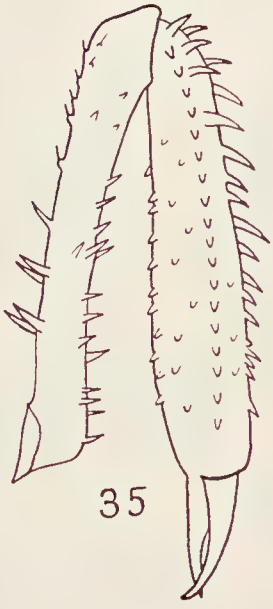
The ovipositor (fig. 40) is long and cylindrical. It is composed of about 19 dark-brown annular segments, each of which in the distal half is surrounded by eight setae. The distal end of the ovipositor is divided into two finger-like lobes, each of which is composed of three segments, and bears on the outer side near the apex a small hemispherical setose sensory organ.

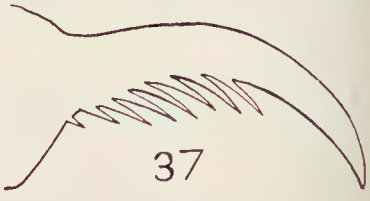
Localities: The holotype male was collected in the Myrtle Gully, Cascades, Tasmania, 26th February, 1945, and the allotype female at Hastings, Tasmania, 21st November, 1939. The species is widely distributed in the State. The collection contains specimens from Trevallyn, Forth Falls, Western Creek, Table Cape, National Park, Great Lake region and elsewhere. Adults are usually found during the period November to April. The species occurs under logs and stones in damp and shady situations.











Spinicrus nigricans sp. n.

Fig. 34.—Dorsal view of body of male.
Fig. 35.—Retrolateral view of chelicera of male.
Fig. 36.—Chela of chelicera.
Fig. 37.—Claw of pedipalpus.
Fig. 38.—Distal end of penis.
Fig. 39.—Lateral view of glans.
Fig. 40.—Ovipositor.

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I am much indebted to the late Messrs. A. L. Meston and G. Craw, who made it possible for me to collect harvestmen in many parts of Tasmania. I am also grateful to the Trustees of the John Ralston Bequest, under whose auspices the above investigation was carried out. My thanks are also due to Messrs. D. E. Kurth and J. L. Hickman for assistance in obtaining specimens.

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THE PRECAMBRIAN ROCKS OF TASMANIA, PART I, DOLERITES OF THE NORTH-WEST COAST OF TASMANIA

By

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(With 4 Text Figures and 2 Plates)

ABSTRACT

At least 30 small bodies of dolerite have been found intruding sediments of the Pre-Cambrian Rocky Cape Group along the coast between Sulphur Creek and Crayfish Creek. The igneous bodies are chiefly sills although dykes also occur. The dolerites are characterized by strong deuteric alteration which led to the formation of secondary tremolite-actinolite, chlorite, zoisite, albite, calcite, sericite, sphene, leucoxene, serpentine, and prehnite. These rocks show petrological and chemical affinities with dolerites of a similar age in Western and South Australia. They have certain features in common with the lavas of the Cambrian Dundas Group, but the possibility that these bodies acted as feeders to the flows is discounted on structural and chemical grounds.

INTRODUCTION

The dolerites occur as small bodies, ranging in size from a few inches to 400 feet in thickness and, as they are less resistant to weathering than the sediments they intrude, most are only revealed in the coastal rock platform. They outcrop sporadically along the coast from Blythe Heads to Crayfish Creek, but the greatest concentration is between Burnie and Cooee Point so that it is intended to use the term *Cooee Dolerite* to refer to this group of igneous rocks as a whole. It is believed that similar rocks occurring in the vicinity of Frenchman's Cap are part of this group and that as mapping of the Pre-Cambrian continues, more will be found. The Cooee Dolerites thus represent a distinct period of igneous activity, probably late in the Pre-Cambrian. Evidence shown later in this paper indicates that the Middle to Upper Cambrian volcanism was a later and distinct episode. A widespread period of basic to ultrabasic activity earlier in the Pre-Cambrian is represented by amphibolites, &c., and the Interview River dyke swarm described by Spry and Ford (1957) belongs to this episode.

Acknowledgements

The author is grateful to W. St. C. Manson of the Tasmanian Department of Mines who carried out the four chemical analyses which are published by courtesy of the Director of Mines. B. May and A. Rundle assisted in the field work.

Previous Literature

The presence of these basic dykes was first recorded by Twelvetrees (1903, 1905) who found them at Burnie, Boat Harbour and Rocky Cape. Stephens (1909) also briefly mentioned the same bodies in his notes on a traverse along the north-west coast.

COUNTRY ROCKS

The dolerites intrude a group of unfossiliferous sediments which extend from Penguin to Smithton. These sediments consist chiefly of quartzites and slates with siltstones, dolomites and a little conglomerate. They were referred to broadly as the "Rocky Cape quartzites" by Twelvetrees (1903, 1905), but examination now shows that the sediments constitute a group. Thus the Rocky Cape Group is here defined as those sediments, chiefly quartzites, slates, dolomites and siltstones outcropping intermittently from Penguin to Smithton and lying unconformably below the Dundas Group (at Penguin). Its thickness is in excess of 10,000 feet and while the detailed stratigraphy is not yet known, a number of formations have been recognized. A small area of coarse mica-schist along the Inglis River, shown in fig. 1, may lie unconformably below this group but the base of the Rocky Cape Group has not yet been seen. The formations are discussed in order (tentative only) from oldest to youngest.

Burnie Quartzite and Slate

This formation contains those quartzites and slates outcropping along the foreshore at West Burnie. It appears to outcrop from east of Howth to Doctor's Rocks, except where covered by a superficial layer of later material. The formation is probably several thousand feet thick and consists mostly of a monotonous repetition of thin slates and quartzites. The argillites are dark-grey to black siltstones or slates which show a cleavage which is strongly developed in some specimens but lacking in others. Some contain abundant clastic mica and others are graphitic. Many of the coarser siltstones exhibit cross-bedding, scouring and other intraformational structures. The quartzites are generally light-coloured, quartzose, and massive, flaggy or thinly bedded with occasional cross bed-

For "Pre-Cambrian" read "Precambrian" throughout the paper.

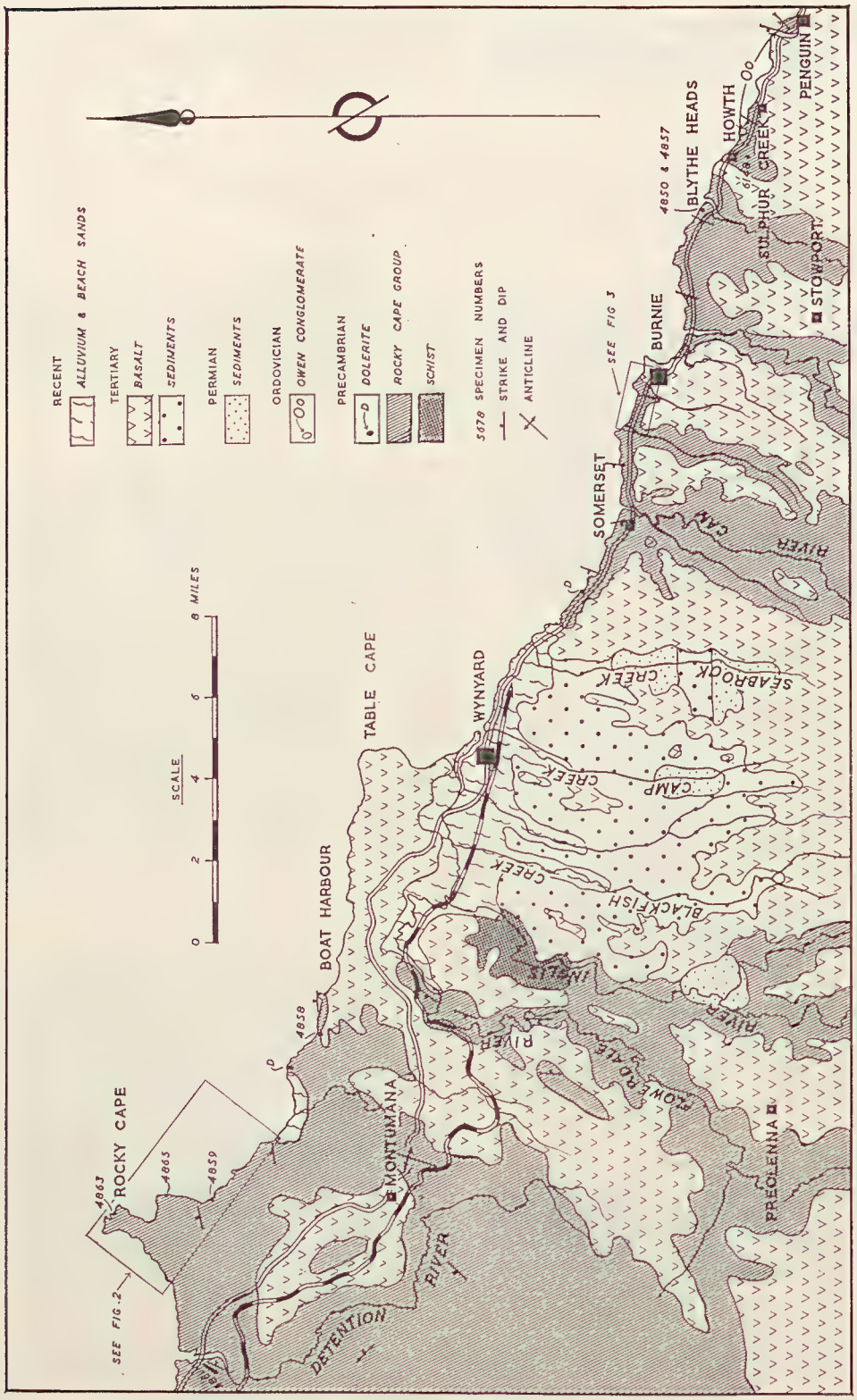


FIG. 1.—Regional geological map showing the distribution of the Precambrian rocks and in particular of the dolerites. Some boundaries after Loveday (1956).

ding. Thin sections of many quartzites show that they contain angular quartz fragments and this fact, together with their association with some beds of sub-greywacke, indicate that they are not normal ortho-quartzites (Pettijohn, 1949). Some arenite layers contain abundant angular slate fragments up to eight inches long and the location of these intraformational breccias is shown in fig. 3.

The lack of recognizable marker horizons, together with the close folding and faulting (see fig. 3) prevents the accurate measurement of the thickness of this formation. The beds generally dip to the west (see fig. 1), but small folds are abundant and these are asymmetrical with the steeper limb either to the east or west, but with a general flat plunge in a direction 230°. Faults are common and cause difficulty in interpreting the structure, and are frequently associated with zones of contortion.

The phyllites at Somerset are more altered and are strongly cleaved with a distinct lineation due to crenulation, but there appears to be a complete transition into the less altered beds at Burnie. These phyllites are overfolded towards the south in the quarry on the Somerset-Waratah road, half a mile south of Somerset and several other places on the wave-cut platform near Somerset.

Black River Dolomite

The Burnie Slate and Quartzite is separated from the sediments in the Rocky Cape area by a cover of Permian sediments and Tertiary lacustrine beds and volcanic rocks, consequently the relationships between the sediments of the two areas is not known. The oldest bed named in this paper from the Rocky Cape area is the thin (50 feet) grey to buff dolomite which outcrops at the bridge where the Bass Highway crosses the Black River. It is brecciated and silicified in parts. A small area of dolomite at the eastern end of Sisters Beach may be the same formation. The Black River Dolomite underlies the Cowrie Siltstone and overlies the unnamed siltstones which occur to the south up the Black River where they are folded into a series of anticlines and synclines about half a mile across, with axes running approximately east-west.

Cowrie Siltstone

The type of locality for this and the following three formations is on the southern part of the western side of Rocky Cape as shown in fig. 3. The name is taken from Cowrie Pt. and it is considered that the formation occurs all the way along the coast from Rocky Cape to Black River although it cannot be proved at present that there is not a fault separating the Cowrie Pt. rocks from those at Rocky Cape where the sequence was established. Thus the Cowrie Siltstone probably lies above the Black River Dolomite and below the Bluff Quartzite. It consists of at least 1500 feet of laminated to flaggy siltstones which are buff, grey and black in colour with a distinct cleavage at an angle to the bedding. They are characterised by possessing intraformational structures such as cross-bedding and slumping, with pyrite nodules in some bands. Thin layers of quartzite occur throughout.

Bluff Quartzite

This is a 1500 foot thick quartzite, light in colour, thinly bedded at the top, but massive towards the base, with coarse cross-bedding and ripple marks (plate I). It overlies the Cowrie Siltstone and lies below the Port Quartzite and Slate. It is lithologically indistinguishable from the Cave Quartzite (defined below) and this causes great difficulty in mapping this area.

Port Slate and Quartzite

This formation is named after the small harbour on the eastern side of Rocky Cape, this being shown as "The Port" on old maps of the area. It lies between the older Bluff Quartzite and the younger Cave Quartzite. It consists of 1500 feet of alternating slates and quartzites. The argillites are grey to black laminated slates and slatey siltstones containing abundant intraformational structures such as sandy lenses, mud pellet conglomerate and slump structures. The quartzites are generally thinly bedded.

Cave Quartzite

The quartzite which forms the extremity of Rocky Cape is called the Cave Quartzite from the Rocky Cape Caves which occur within it. It overlies the Port Slate and Quartzite but the upper limit is not visible. It consists of 1500 feet of light coloured, thickly bedded quartzite with some cross-bedding and ripple marks. The quartzite on the cliffs east of Sisters Beach and at Jacob's Boat Harbour is probably this formation. Exposed in a raised sea cave half a mile east of Sisters Beach is a conglomerate which is named the Sisters Conglomerate, being a member within the Cave Quartzite. The conglomerate occurs as two closely spaced horizons one of which is about 18 feet thick and the other about three feet thick. There are coarse and fine phases but the well-rounded boulders (which are always quartzite identical with that above and below) range up to 18 feet long.

The quartzite at the eastern end of Sisters Beach is of interest as it contains the only trace of organic life in the Rocky Cape Group. Plate II shows a specimen of "worm tracks".

The Cave Quartzite may be equivalent to the Bryant Hill Quartzite named by Carey and Scott (1952) at Smithton where it underlies the Smithton Dolomite. These two formations were referred to as "Carbine Group" by correlation with Elliston's (1954) section at Dundas.

Field mapping has shown that the stratigraphy of the Pre-Cambrian rocks is very complicated and consequently, any correlation of the extensive sediments around Smithton and Rocky Cape with the imperfectly known Carbine Group of Dundas, is unwise at present.

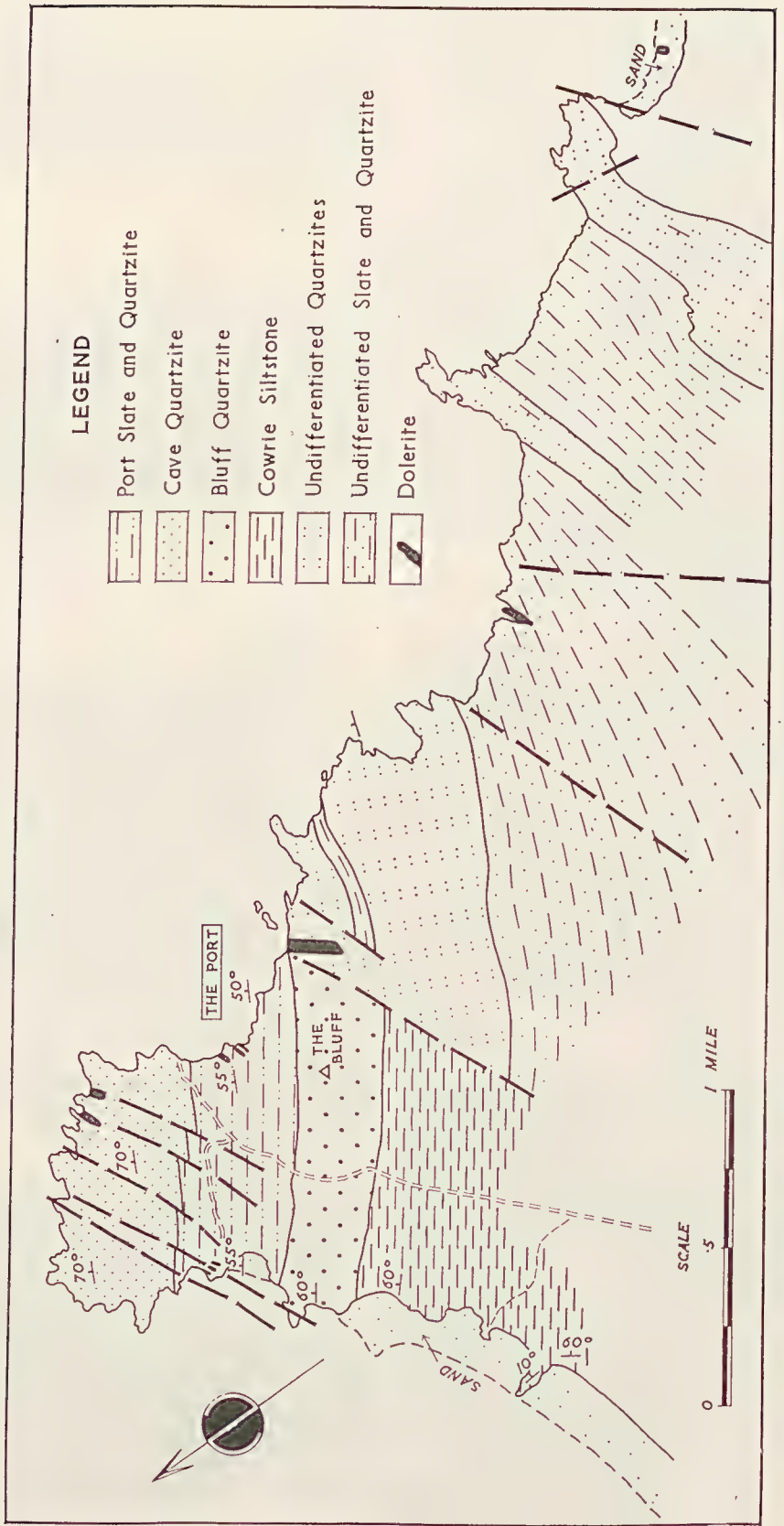


FIG. 2.—Sketch map of Rocky Cape showing the type localities for the named Precambrian formations and also some dolerites.

FIELD RELATIONS OF THE DOLERITES

Sulphur Creek

The most easterly occurrence is near Sulphur Creek where a few boulders of brecciated, fine-grained dolerite are scattered around on the northern slope of the hill about one third of a mile south of the coast, as shown in fig. 1. The field relations are unknown but it appears to have originated in an old adit which apparently explored the pyrite mineralization in the igneous rock.

Blythe Heads

Three sills outcrop on the wave-cut platform north-north-east of the Titan Products factory about half a mile west of the mouth of the Blythe River. Two of the sills are about 100 feet thick while the other is about 12 feet thick. They concordantly intrude quartzites (probably belonging to the Burnie Slate and Quartzite) which dip to the west at 45°. A very crude banding in the thicker sills is due to alternation of coarser and finer grained layers.

Burnie-Cooee Pt.

Dolerite outcrops on the rock platform at West Burnie, as shown in fig. 3. There is probably more inland, but due to the extensive cover of Tertiary basalt the only one found was that in the Brickport Road quarry, about a quarter of a mile south of Cooee Pt. This particular rock is strongly weathered and is being quarried for brickmaking. It occurs as a 300 feet thick sill striking at 15° and dipping west at 50°. Medium and coarse grained phases are separated by a fault surface. The body probably continues beneath soil cover to outcrop poorly in the bay next to the Cooee Railway Station.

The dolerites are well exposed along the platform at West Burnie, but because of the structural complexity and limit of outcrop, it is not possible to state definitely how many individual bodies are present, despite detailed mapping. Fig. 3 shows the distribution of the dolerite together with an interpretive section. It seems most likely that there is one major sill 300 feet thick which outcrops on the shore from Cooee Pt. to Noel St. and possibly again at Park Pt. It is commonly pegmatitic and the country rocks immediately beneath are generally cut by many very thin sills (Plate I, No. 4). There are at least two other sills about 100 feet thick, as well as many smaller ones ranging from 15 feet to 4 inches in thickness. The uniformity of the sediments which have been intruded and the lack of marker horizons prevent the detailed structure from being recognized, especially as there appear to be at least four strike faults with throws of several hundred feet.

One structural characteristic is shown by several bodies here. The upper surface is concordant with the overlying sediments which dip at a moderate angle. The strike of the lower surface is parallel to that of the upper but the dip of both sediment and base of the sill is very steep, often vertical. This may represent an intrusion along a fault, the section across the tightly bent crest of a fold, or a post-intrusion fault along one side of the body.

The intrusions here are generally quite concordant although they show clearly discordant boundaries in some places. Fig. 3 shows a folded sill which transgresses the sediments in a zone between two concordant parts.

Somerset

A small dolerite body on the wave-cut platform about two miles west of Somerset occupies the core of a small anticline in quartzites.

Jacob's Boat Harbour

A sill 100 feet in thickness on the rock platform about one mile west of Boat Harbour intrudes quartzites and slates striking at 50° and dipping 50° to the north-west. The sediments probably are equivalent to the Port Quartzite and Slate. A second dyke occurs two miles west of Boat Harbour and a quarter of a mile east of the end of Sisters Beach. This may intrude the same formation but the structure is not clear.

Rocky Cape

Eleven intrusions at Rocky Cape are shown in fig. 3. On the eastern side of the extremity of the Cape are two dykes which strike at 240° and intrude Cave Quartzite which strikes 280° and dips up to 70° north. On the rock platform extending for a quarter of a mile south of the end of the road to the old jetty are three sills and a dyke intruding Port Quartzite and Slate. The thickest sill is 100 feet thick. The dyke is visible on a small stack where it strikes at 50° across sediments striking at 115°. Several more dykes outcrop on the south-easterly part of the Cape and another on the western end of Sisters Beach. Five small dykes intrude the Port Quartzite and Slate on the rock platform on the west side of the Cape, opposite the jetty.

Detention River

A few hundred yards west of the intersection of the Detention River and the Bass Highway is a low ridge standing about 20 feet above the surrounding flat country. It is composed of dolerite which forms a sill intruding pale coloured flaggy quartzites striking at 220° and dipping east at 20° to 30°. A little pyritization of the quartzites is visible in the small quarry near the road. The sill may be followed for a mile to the south before it is lost beneath a cover of gravels.

Crayfish Creek

A small dyke on the foreshore about half a mile east of Crayfish Creek intrudes the Cowrie Siltstone. The sediments are blue and grey, well bedded to laminated siltstones and impure quartzites striking east-west and dipping north at angles of 45° and higher.

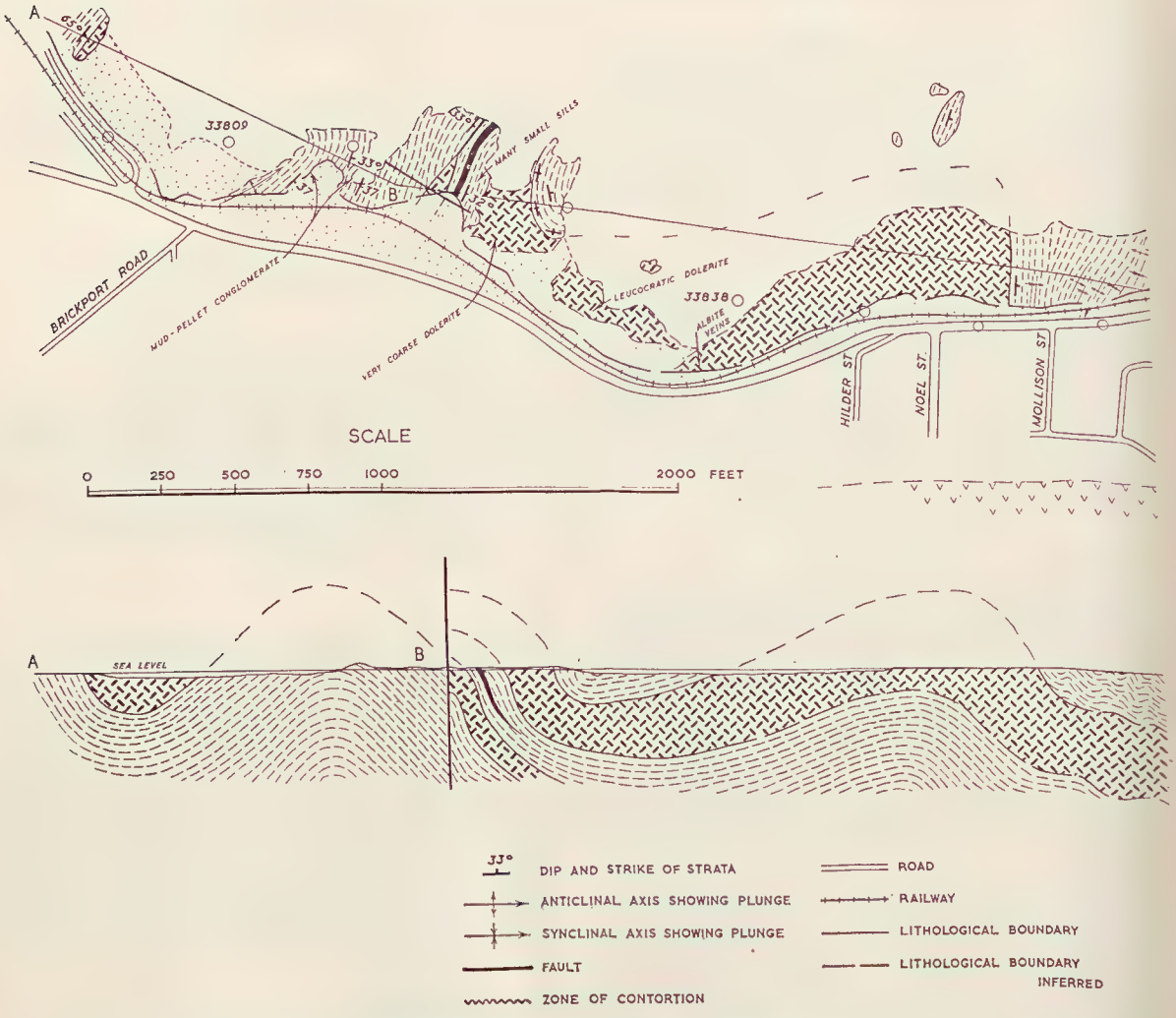


FIG. 3.—Precambrian sediments (Burnie Slate and Quartzite) with dolerite intrusions on the foreshore between Cooee Point and Park Point, West Burnie.

STRUCTURAL RELATIONS

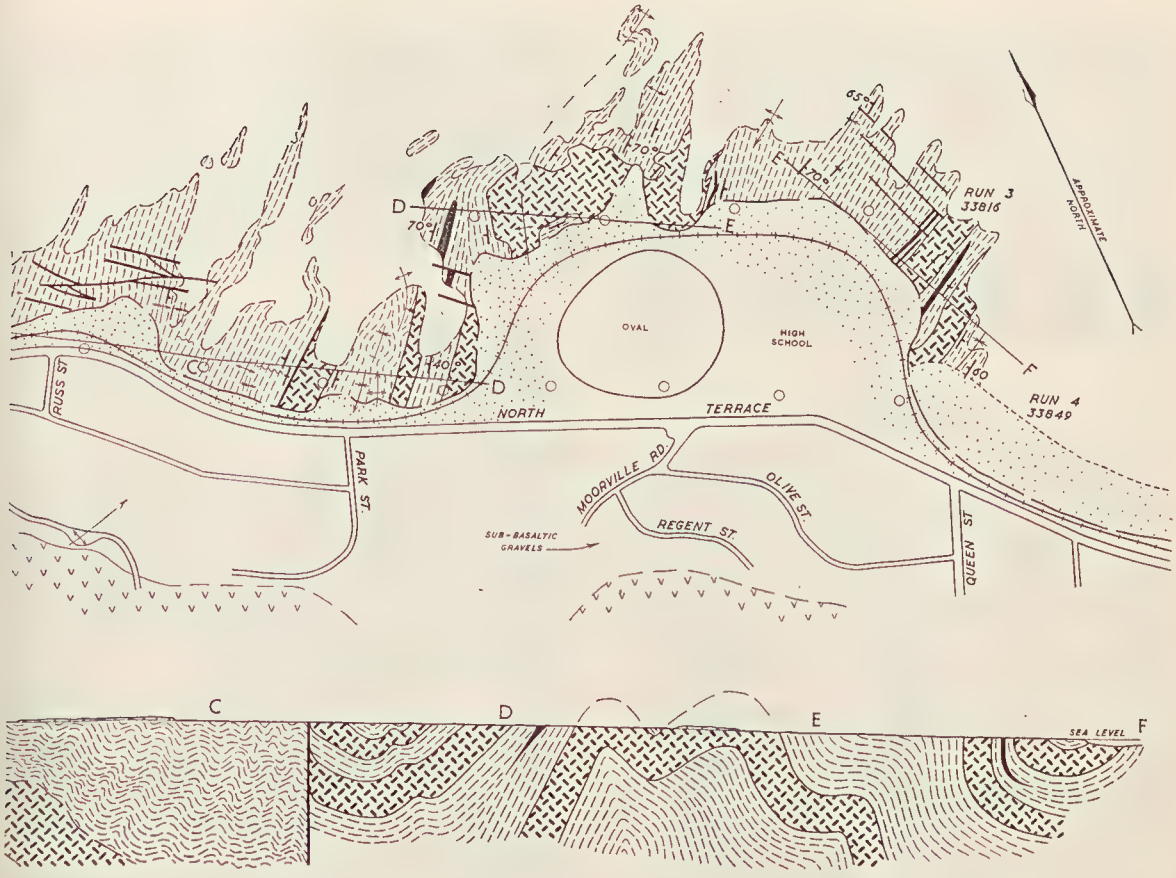
It is possible to divide the dolerites into two groups on structural, geographic and petrological grounds. The intrusions west of Wynyard (i.e., Boat Harbour, Sisters Beach, Rocky Cape, Detention River and Crayfish Creek) are chiefly dykes and show very marked secondary alteration. It is noticeable that practically all of these intrusions strike north-easterly and only a few diverge even as much as 30° from this direction. Not only is this the direction of a prominent set of faults in this area, but the dykes themselves actually lie along faults on the northern end of Rocky Cape.

The intrusions east of Wynyard (i.e., Somerset, Burnie and Blythe Heads) are all sills and show secondary alteration to a lesser degree than those of Rocky Cape, &c. The Detention River Sill shows characteristics common to each group.

The evidence suggests that the easterly group were intruded either prior to, or contemporaneously with, the folding, whereas the westerly group were intruded during the faulting which followed the folding. The two phases are considered to be parts of one period of igneous activity.

MINERALOGY

The dolerites probably originally consisted chiefly of pyroxene and labradorite with minor amounts of brown hornblende, biotite and olivine in some specimens. Accessories are apatite and ilmenite. Secondary minerals are tremolite-actinolite, chlorite, zoisite, sericite, prehnite, albite, leucoxene, sphene, calcite and serpentine.



Primary Minerals

Pyroxene

Most rocks contain relics of pyroxene which show partial alteration to pale fibrous amphibole or chlorite. Some leucocratic dolerite from Burnie and dolerites outcropping from Boat Harbour to Rocky Cape show complete alteration of the pyroxene. The pyroxene is more resistant to alteration than the plagioclase and persists after all plagioclase has been replaced. This relation has been observed repeatedly in similar rocks and has been discussed by Spry (1952, p. 104).

The pyroxene is generally colourless in thin section although very pale-green varieties occur. Purple titanaugite occurs in specimens from Burnie (4868*) and Blythe Heads (4857).

The optic axial angle ranges from 45° to 66°. In a specimen from Detention River (4855) the pyroxenes are zoned with a 2V of 45° in the centre to 49° at the edge and measurements of other crystals in the same slide gave values of 48°, 52° and 58°.

An analysis of the pyroxene from the Blythe Heads dolerite (4857) is given in table 1. It is black in hand specimen, deep purple in crushed grains and in thin section is a pale-purple drab (Munsel Colour Chart). It has $2V = 66°$, and $\beta = 1{\cdot}665 \pm {\cdot}003$. The analysis shows several interesting features. Titania is quite high as many titanaugites only contain 1 per cent. The iron content is rather

* Numbers refer to specimens in the collection of the Geology Department, University of Tasmania.

low, as is the lime. The alumina is high (9%) as most augites range from 2-8 per cent. The total of 1·05 per cent alkalis is appreciable although Hess (1949, p. 654) recorded an augite with Na_2O = 1·61 per cent and K_2O = ·06 per cent. The 2·85 per cent of water is unexpected as the sample appeared to be completely fresh but the slight amount of P_2O_5 is due to a small but persistent apatite contamination.

The pyroxene is compared with one from a Cambrian spilite of the Dundas Group, analysed by Scott (1954). The similarities (e.g., high alumina and low iron) are pronounced although there are slight differences in 2V, titania content and colour.

TABLE 1

PYROXENE ANALYSES

	Blythe Heads Analyst: W. St. C. Manson	Lynch Creek (Scott, 1954) Analyst: B. Scott
SiO_2	46·10	48·53
Al_2O_3	9·00	7·10
Fe_2O_3	1·90	0·70
FeO	7·00	5·71
MnO	0·18	not det.
TiO_2	1·60	0·85
P_2O_5	0·15	not det.
CaO	17·70	21·24
MgO	12·60	15·90
Na_2O	0·84	not det.
K_2O	0·21	not det.
H_2O—	0·14	not det.
H_2O+	2·71	not det.
	100·13	100·03

ATOMIC PERCENTAGE

	Blythe Heads	Lynch Creek (Scott, 1954)
Ca	42·0	46·7
Mg	41·9	42·3
Fe	16·1	11·0
Percentage Al in Z	14·3	—
2V	+66°	+51°

Plagioclase

No primary plagioclase was found in any of these rocks and the albite, zoisite, calcite and prehnite are considered to have been derived from original basic plagioclase.

Orthoclase

It is difficult to recognise orthoclase among the strongly altered feldspar, all of which is crowded with tiny inclusions but the analyses in table 2 indicate its presence. The mineral is usually sericitized, e.g., 7265, but occurs in a fresh condition as an intergranular graphic intergrowth with quartz in the Detention River sill (4861).

Hornblende

Several rocks contain large laths of hornblende which are so well formed as to be probably primary. This is abundant in the coarse phase of the dolerite (4856) near Cooee Pt. where crystals up to 1·5 cms. long are visible in the hand specimen. The mineral is pleochroic with X = pale-green, Y = reddish-green and Z = deep green to rusty-brown and has $Z \wedge C = 13°$. A little olive-green hornblende is developed in other specimens but its somewhat ragged shape suggests that it may be secondary.

Olivine

Some dolerites (4855, 7276) from just west of Burnie contain a few crystals which have the typical shape of euhedral olivine but which now consist of serpentine.

Biotite

Some dolerites, particularly those at Burnie (4855, 4860, 4864) contain a little well-formed biotite which appears to be primary. It is fresh and pale-green in 4858 but is generally strongly pleochroic from pale rusty-yellow to deep brownish-black (4864) with peripheral alteration to chlorite. The crystals are not greater than ·2 mm. in length and the chilled dolerites are rich in very tiny crystallites of biotite.

Quartz

Apart from very minor amounts in the dolerites from Detention River (4861) and Rocky Cape (4853, 4854), the only rocks in which quartz is important are the leucocratic varieties from Burnie. Quartz veins cut the dolerite at Burnie.

Ilmenite

This is an accessory in all of the dolerites. It forms irregular crystals which measure as much as 2 mm. across and which are partially or entirely replaced by either leucoxene or sphene.

Apatite

This is an abundant accessory in all of the dolerites. It appears as colourless hexagonal prisms and needles which reach 3·3 mm. long in 4864 and 7265.

Secondary Minerals

The primary minerals show various degress of alteration and this is made a basis of subdivision of the dolerites in a later section.

Amphibole

This is well developed in some specimens where it has either replaced pyroxene or forms peripheral fringes around it. The amphibole is fibrous and varies from colourless through various shades of pale-green to olive-green. A tremolitic variety is present in the leucocratic dolerite (4851); it is pleochroic from colourless to palest-yellow, has an optic axial angle of approximately 80° (negative) and an extinction angle $Z \wedge C$ of 16°.

Chlorite

Chlorite is the most common alteration product of pyroxene and it has also replaced biotite and feldspar (4859, 4855). It is poorly crystallized as fine fibres or flakes which form clots, shapeless intergranular patches or pseudomorphs after pyroxene. Its properties are difficult to obtain but it is colourless to palest-green and varies from isotropic to weakly birefringent with anomalous interference colours and appears to be optically positive with a very low optic axial angle.

Albite

A plagioclase close to pure albite (Ab_{98}) is present in all of these rocks and is regarded as being due to the breakdown of original labradorite. It shows a considerable variation in its properties. Most albite occurs as large, well-formed laths pseudomorphing original plagioclase and is strongly clouded by innumerable tiny inclusions of zoisite, sericite, kaolinite (?), chlorite or sphene. It commonly displays twinning on the Albite Law.

Albite also occurs as small, shapeless, intergranular crystals which are fresh and untwinned.

The albite in the leucocratic dolerites is generally anhedral and fairly fresh. Some is untwinned (4862), some shows poor twinning on combinations of the Albite and Carlsbad Laws (4851) and some shows fine chequer-board twinning (4860). One specimen (4851) contained feldspar showing slight compositional and alteration zoning.

There are drusy veins an inch or so thick of creamy-white, euhedral albite cutting the dolerite at Burnie in the locality shown in fig. 3.

Prehnite

This is a secondary product formed by the alteration of original plagioclase and occurs abundantly in some specimens from Burnie (4855) and in small amounts in rocks from Detention River (4861), Rocky Cape (4863) and Boat Harbour (4858). In thin section, it is colourless and coarsely crystalline to fibrous or scaly and shows the undulose extinction which is characteristic of this mineral. The birefringence is about ·032 and it is optically positive with a moderate but very variable 2V.

Zoisite-Epidote

Zoisite occurs commonly in these rocks and it represents the lime liberated in the breakdown of labradorite to albite. It is generally small in size (·02 mm. granules) but some well-formed prisms reach ·5 mm. in length. The birefringence is very low and anomalous blue interference colours are prominent. Extinction is straight and it is colourless to pale-green.

In some specimens the colourless zoisite grades into a pale-yellow, ferroan zoisite with a little higher birefringence, or into yellow epidote with much higher birefringence and oblique extinction. An irregular form of twinning is shown by some crystals.

Leucoxene

Fine-grained growths of leucoxene partially or wholly replace ilmenite in all of the dolerites.

Sphene

Small grains (not usually more than ·01 mm. diameter) of pale-brown sphene occur in a few rocks (4860) where it is probably due to the concurrent breakdown of plagioclase and ilmenite.

Calcite

This mineral occurs sporadically both in small grains and large crystals. It is quite abundant in the leucocratic dolerite, e.g., 4862.

Serpentine

There are uncommon crystals of olivine which have been pseudomorphed by pale-green fibrous serpentine with anomalous blue interference colours.

PETROLOGY

All these igneous rocks show strong similarities to each other and there is no doubt that they are closely related genetically. It is convenient to divide the rocks up into groups on petrographic grounds but the differences between groups are not great and it is considered that there is one chief type (referred to as group "a" below) and that the others have been derived from this by chilling, secondary alteration, slight differentiation or fragmentation.

The following rock types have been observed:—

(*a*) moderately altered dolerites,
(*b*) strongly altered dolerites,
(*c*) micro-dolerites,
(*d*) brecciated micro-dolerite,
(*e*) basic pegmatite (pegmatitic dolerite),
(*f*) leucocratic dolerite.

(*a*) The most important group consists of moderately altered dolerites with mildly alkaline affinities. Many of the dolerites at Burnie (4864, 4855) are of this kind, as are those at Blythe Heads (4857) and Detention River (4861). Analyses are given in table 2.

These are greenish-grey dolerites with a rather coarse grain. In thin section they show an intergranular to ophitic texture which has been partially destroyed by the growth of secondary minerals. The pyroxene is a titanaugite (analysis in table 1) which is generally fresh but which has inclusions of zoisite and sphene in some specimens and a partial alteration to fibrous amphibole or chlorite in others.

The plagioclase laths are of albite which is either strongly obscured by inclusions of zoisite, is altered partially or wholly to sericite, or is replaced by prehnite.

Orthoclase is recognisable as cloudy anhedral crystals which are less obscured by inclusions than the albite. It also occurs as micro-graphic intergrowths with quartz in the Detention River sill.

A little, large, well-formed brown hornblende occurs in some specimens together with biotite. Accessory ilmenite with leucoxene, and apatite are present. A little olivine altered to serpentine was found in two specimens.

TABLE 2

ANALYSES OF DOLERITES

(Analyst: W. St. C. Manson)

	4864 Coarse dolerite Burnie	4852 Dolerite Detention River	4861 Leucocratic dolerite Burnie
SiO_2	44·44	58·52	54·64
Al_2O_3	17·97	15·03	15·22
Fe_2O_3	1·74	0·96	1·17
FeO	8·32	2·60	7·81
MnO	0·22	0·11	0·13
CaO	9·42	8·46	7·96
MgO	4·74	4·36	5·39
Na_2O	2·86	3·24	1·69
K_2O	3·04	1·41	2·23
TiO_2	3·00	0·41	0·68
P_2O_5	0·72	0·12	0·10
H_2O-	0·26	0·14	0·02
H_2O+	3·53	5·09 (inc. CO_2)	2·85
	100·26	100·45	99·89

(*b*) The dolerites which occur between Rocky Cape and Boat Harbour are much more altered than the previously described rocks. Examples of this group are 4853, 4854, 4859 and 4863.

The original ophitic to intergranular texture has been almost, if not completely, destroyed by the growth of new minerals. No original plagioclase remains and only in a few cases is pyroxene found. The rocks are composed chiefly of fibrous actinolite, chlorite, albite, zoisite and leucoxene with varying amounts of prehnite, sericite, biotite and quartz. Ilmenite is very abundant in 4863 from Rocky Cape.

Specimen 4858 from west of Boat Harbour contains completely prehnitized feldspar outlined by lines of epidote grains, colourless to olive-green actinolite with cores of chlorite, a little brown hornblende surrounded by growths of actinolite, ilmenite rimned with sphene, and tiny flakes of fresh green biotite.

Specimen 4859 from Rocky Cape contains approximately 35 per cent actinolite, 35 per cent biotite, 15 per cent epidote and zoisite, 5 per cent ilmenite partially replaced by leucoxene and 10 per cent of feldspar, &c. In this rock there are large (2·5 mm.) crystals of plagioclase which have been replaced by chlorite and zoisite.

(*c*) The thin (2 feet and less) sills which are abundant just west of Burnie, particularly near Cooee, have a fine grain due to rapid chilling, and these are best named micro-dolerites. Typical specimens are 7266, 7270 and 7271.

In the hand specimen, they are dense, dark-grey to black, very fine-grained, somewhat spotted rocks. In thin section they are seen to consist of a fine-grained mesh of albite laths with chlorite and abundant iron oxide. Tiny biotite flakes, some chloritized, are arranged in a criss-cross fashion, and finely granular calcite is present. A little epidote occurs in one specimen.

(*d*) The rock (6048) from Sulphur Creek appears to be a brecciated micro-dolerite which has been cemented by calcite. It consists of pale, greenish-grey, fine-grained fragments averaging about 1 cm. across, with a white, calcite cement. There are a few grains of chalcopyrite. In thin section, the fragments are seen to be very fine grained and strongly altered with a flow structure. There are tiny laths of albite set in a dark groundmass. The cement is chiefly of calcite with tiny rhombs of dolomite and some strongly undulose quartz.

(*e*) A coarse-grained pegmatitic rock occurs as irregular patches within the large sill at Burnie, particularly on the beach opposite Hilder Street.

Number 4856 consists of large laths of brown hornblende up to 1·5 cms. long with similarly sized fresh titanaugite crystals set in a finer mesh of altered plagioclase. The feldspar has been prehnitized but fresh albite showing chequerboard twinning is abundant. Leucoxene forms masses up to 2 mm. across and apatite occurs as needles almost 1 cm. long.

Number 7265 contains abundant, large, euhedral hornblende crystals which have grown around fresh titanaugite in optical continuity. Large, fresh biotite crystals are present.

(*f*) The leucocratic dolerites (4851, 4852, 4862) occur as narrow veins of pale-grey to cream, fine-grained rock cutting the dolerite on the beach west of Hilder Street. They shown an allotriomorphic granular texture and consist chiefly of albite, tremolite (after pyroxene which remains as small cores in some rocks), quartz, chlorite, calcite, apatite, ilmenite, leucoxene and sphene. The albite ranges from strongly clouded to fresh crystals and is untwinned, twinned on a combination of the Albite and Carlsbad laws or shows fine chequerboard twinning.

The composition is variable and ranges from 80 per cent albite and 20 per cent of epidote, zoisite, chlorite, biotite, ilmenite, pyrite and sphene in No. 4860 to 35 per cent albite, 20 per cent calcite, 15 per cent quartz and 20 per cent chlorite in No. 4862.

These rocks show affinities with the keratophyres and an analysis is given in table 2. A similar rock was described by Spry (1952) from Hawker, South Australia, where it was shown to have been formed by differentiation from similar dolerites.

As can be seen from the petrographic descriptions, all of these rocks show distinct similarities and can be genetically related as follows. First was the rise of olivine basalt magma from the sima into a deep crustal chamber. Early olivine crystallized and settled and this caused the initial magma which intruded the Rocky Cape Group to be rich in water and somewhat tholeiitic. The residual volatiles caused the secondary alteration of early silicates during the deuteric phase of crystallization as outlined for similar rocks by Spry (1952). Concentration of volatiles in certain areas during the initial phases of crystallization resulted in an increase in grainsize and gave the patches of pegmatitic dolerite. Some slight tectonic movements during crystallization resulted

in differentiation by "filter-press" action with a less basic residual magma migrating into fissures in the partially solidified dolerite to crystallize as small bodies of leucocratic dolerite.

Structural evidence shows that the dolerites at Rocky Cape were intruded a little later, and the petrological evidence is in accord as it points to a higher concentration of volatiles in the later intrusives. Fractions drawn from a cooling magma reservoir would be progressively richer in volatiles as time passed.

Related Rocks

Dykes of similar rock have been found intruding the Pre-Cambrian 70 miles to the south at the Raglan and Surveyor Ranges, in the Frenchman's Cap area. These are tentatively correlated with the *Cooee Dolerites* on petrographic grounds.

A number of small dyke-like intrusions outcrop on the Raglan Range along Bradshaw's timber track between Mount Raglan and the huts to the west. The rock is strongly weathered and in some places, merely forms areas of tan-coloured clay. The dolerite intrudes garnet schist. Specimen 6317 is a light-grey dolerite with relics of ferromagnesian minerals visible in the hand specimen. It is fine grained and consists chiefly of interlocking laths of very cloudy albite with chlorite pseudomorphs of the original pyroxene. Opaque minerals are abundant and include pyrite, limonite and magnetite. Apatite is an accessory.

Specimen 6784 was collected by J. B. McKellar south of Frenchman's Cap. It is somewhat porphyritic, with euhedral phenocrysts of sericitized feldspar set in a medium grained, intergranular groundmass which consists of cloudy albite laths and ragged biotite flakes, with a little chlorite and sphene.

The *Cooee Dolerite* show considerable lithological similarities with the lavas of the Cambrian Dundas Group. The spilites and keratophyres of the Dundas Group show pronounced alteration with the development of albite, epidote, chlorite, actinolite, leucoxene and calcite. It has been shown earlier in this paper that the pyroxene from the Cambrian spilite at Lynch Creek is not unlike that from the dolerite at Blythe Heads.

The folded sills at Burnie were intruded simultaneously with, or before the folding of the Rocky Cape Group, whereas the dykes at Rocky Cape were intruded later. As the Rocky Cape Group appears to be conformable with the Dundas at Smithton, it is possible that the folding of the Pre-Cambrian rocks took place in the Cambrian and that these intrusions represent a phase of the Cambrian vulcanicity. It is also possible that the folding took place prior to the Cambrian but that some of the dykes might be the "feeders" of the Cambrian lavas.

In this area the Owen Conglomerate rests directly on the Rocky Cape Group with violent unconformity and it appears that the area from Smithton to Penguin might have been a land mass during the Cambrian. The Dundas Group at Penguin appears to overlie unconformably the Rocky Cape Group.

It thus seems most likely that the Pre-Cambrian sediments were folded before the Cambrian and that the igneous rocks are Pre-Cambrian also. It is shown later that there are considerable chemical differences between the Cooee Dolerite and the Dundas Group.

The similarities between these dolerites and those which intrude Pre-Cambrian rocks in South Australia and Western Australia are very striking. The relationships between the South and Western Australian dolerites were discussed by Spry (1952) and it was suggested that these dolerites showing uralitization, saussuritization, &c., were so distinct in their petrological nature that they could be considered to constitute a petrographic province. The Cooee Dolerite may belong to this province also.

Prider (1945) summarized the characteristics of the Western Australian rocks and it is remarkable that dolerites described by Cole and Gloe (1939) from Malkup resemble some South Australian types down to the last minute detail.

The rocks belonging to this petrographic province may be described as follows. They are medium-grained with a texture ranging from hypidiomorphic granular to intergranular or ophitic. They originally consisted of pyroxene and basic plagioclase with some brown hornblende, accessory ilmenite and apatite and a little olivine in a few cases. A quartz-rich residuum occurs in some rocks. The pyroxene is generally augite, but pigeonite is found in some South and West Australian specimens, and titanaugite in some from Tasmania and West Australia. Secondary alteration is characteristic and has led to the development of actinolite, albite, epidote, zoisite, chlorite, leucoxene, sphene and sericite.

A summary of the chemical data available for the dolerites from Cooee, South Australia and Western Australia is given in table 3.

There are significant similarities between the Cooee Dolerite and those from South and West Australia but the Dundas spilites show marked differences. This is emphasized by the distribution of the analyses in fig. 4. The Na_2O-FeO-MgO diagram used by Sundius (1930) shows that the Dundas spilites differ considerably from the Cooee dolerites which chemically may be grouped with the Western and South Australian rocks.

The compositions are also plotted on a Na_2O-K_2O-MgO diagram to emphasize the importance of the alkalies. Sundius (1930, p. 9) remarked that "undeniably the extreme deficiency in potash is a special character of the spilite series". The high Na_2O and low K_2O is probably the most important characteristic of the spilites and the ratio $\frac{Na_2O}{K_2O}$ is about 6 for Sundius' average spilite and for the Dundas spilites. On the other hand the ratio is about 1 for the Cooee Dolerites, $1\frac{1}{2}$ for the Kimberley rocks, 2 for the West Australian and $2\frac{1}{2}$ for the South Australian basic rocks.

CONCLUSIONS

The petrological and structural evidence suggests very strongly that the Cooee Dolerites and the Dundas spilites represent separate periods of igneous activity. This could be proved if the Dundas was found to overlie unconformably one of the dolerites but the chances of finding this seem remote, due to limitations of outcrop. Radioactive age determinations do not seem likely to help because of the lack of the appropriate minerals.

The dating of this period of igneous activity is difficult but it is probably pre-Dundas, i.e., earlier than Middle Cambrian, and as the Rocky Cape Group is probably Upper Proterozoic, then the dolerites could belong to the Australia-wide group of basic rocks ranging from Late Pre-Cambrian to very Early Proterozoic.

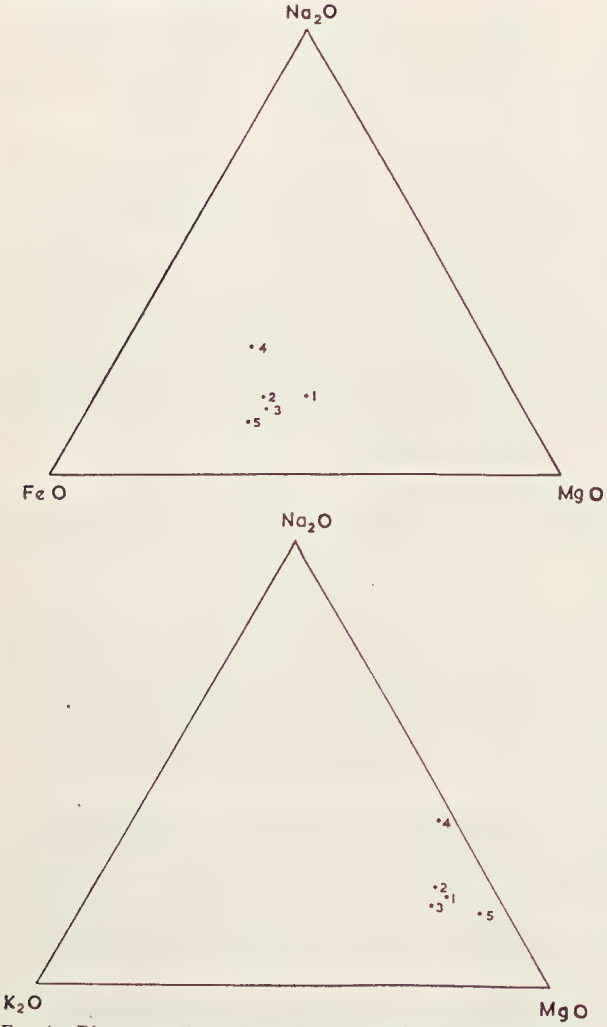


FIG. 4.—Diagrams illustrating the similarities and differences between the compositions of basic rocks from (1) Burnie; (2) South Australia; (3) Western Australia; (4) Kimberley, Western Australia; (5) Dundas Group, Tasmania. See details in table 3.

TABLE 3

ANALYSES OF SOME AUSTRALIAN CAMBRIAN AND PRE-CAMBRIAN BASIC ROCKS

	1	2	3	4	5
SiO_2	52·47	43·42	49·88	49·33	52·27
Al_2O_3	16·07	14·98	13·28	16·39	14·68
Fe_2O_3	1·29	4·21	2·54	2·83	3·88
FeO	6·24	6·21	10·71	8·64	7·70
MnO	0·15	0·16	0·38	0·15	0·25
CaO	8·61	7·47	9·48	7·95	7·61
MgO	4·83	6·09	6·37	4·86	5·09
Na_2O	2·60	2·62	2·21	4·62	2·85
K_2O	2·23	1·05	1·01	0·70	1·97
TiO_2	1·36	1·69	1·73	0·64	1·30
P_2O_5	0·31	0·15	0·24	0·10	—
H_2O—	0·14	2·23	0·14	0·23	0·62
H_2O	3 82	1·56	1·88	2·56	1·03

1. Average of three dolerites from Burnie and Detention River (see Table 2).
2. Average of 10 dolerites and basalts from the Flinders Ranges, South Australia.
3. Average of 10 dolerites from the Pre-Cambrian of Western Australia (Prider, 1945).
4. Average of five spilites from the Dundas Group, Tasmania (Scott, 1954).
5. Average of seven basalts from the Kimberley area, Western Australia (Edwards, 1942).

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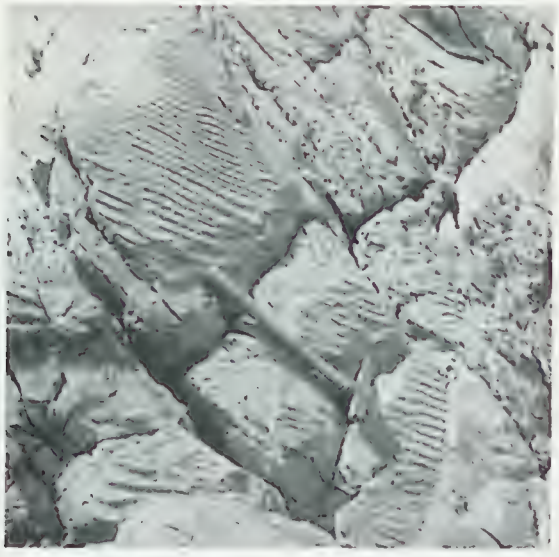
LOCALITY INDEX

	Quadrangles	S. Lat.	E. Long.
Black River	Smithton 21	40° 53′	145° 18′
Blythe Heads	Burnie 28	41° 4′	145° 59′
Boat Harbour	Table Cape 22	40° 58′	145° 38′
Brickport Road Quarry	Burnie 28	41° 4′	145° 53′
Burnie	Burnie 28	41° 3′	145° 55′
Cooee	Burnie 28	41° 4′	145° 53′
Crayfish Creek	Smithton 21	40° 54′	145° 23′
Detention River	Smithton 21 Table Cape 22	40° 58′	145° 30′
Frenchman's Cap	Pillinger 65	42° 17′	145° 50′
Inglis River	Table Cape 22 Burnie 28	41° 0′	145° 38′
Lake Dora	Murchison 51	41° 58′	145° 37′
Lynch Creek	Lyell 58	42° 7′	145° 31′
Penguin	Devonport 29	41° 7′	146° 4′
Raglan Range	Lyell 58	42° 8′	145° 46′
Rocky Cape	Table Cape 22	40° 51′	145° 31′
Sisters Beach	Table Cape 22	40° 55′	145° 33′
Smithton	Smithton 21	40° 50′	145° 8′
Somerset	Burnie 28	41° 3′	145° 51′
Sulphur Creek	Burnie 28 Devonport 29	41° 7′	146°
Surveyor Range	Pillinger 65	42° 24′	145° 52′
Waratah	Valentines Peak 36	41° 27′	145° 32′
Wynyard	Table Cape 22	41° 1′	145° 42′



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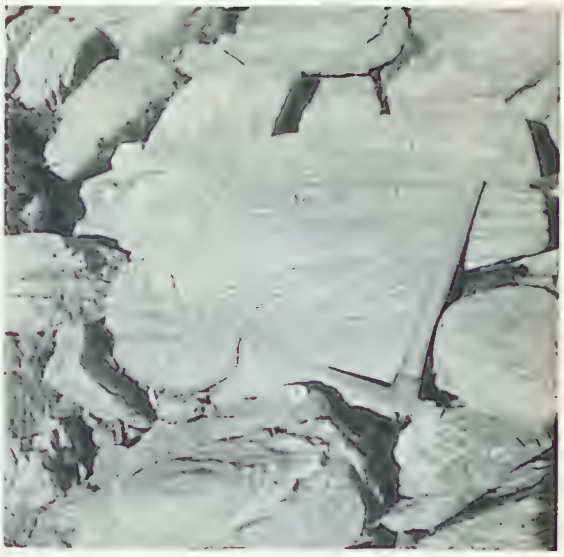

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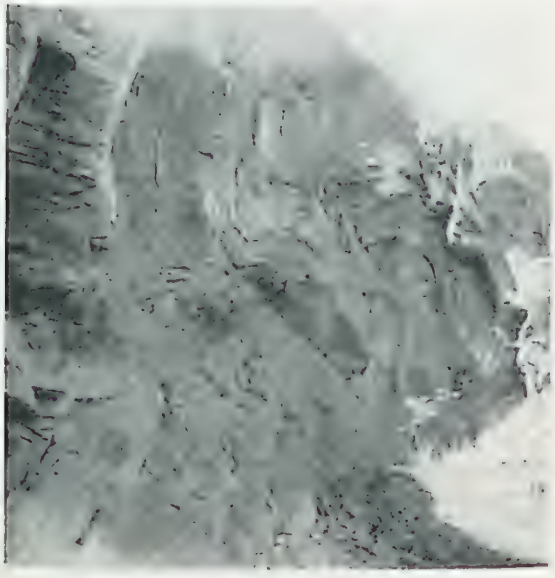

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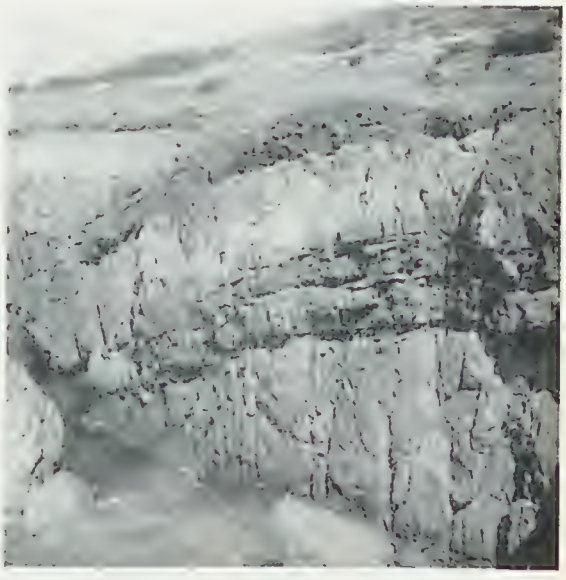

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No. 1.—Ripple marks in the Bluff Quartzite on the eastern side of Rocky Cape.
No. 2.—Cross-bedding in the Bluff Quartzite on the eastern side of Rocky Cape.
No. 3.—Overturned folds in the quarry on the Waratah Road, half a mile south of Somerset.
No. 4.—Thin sills intruding quartzite just beneath the thick sill a quarter of a mile east of Cooee Point. The beach in the background is underlain by dolerite.

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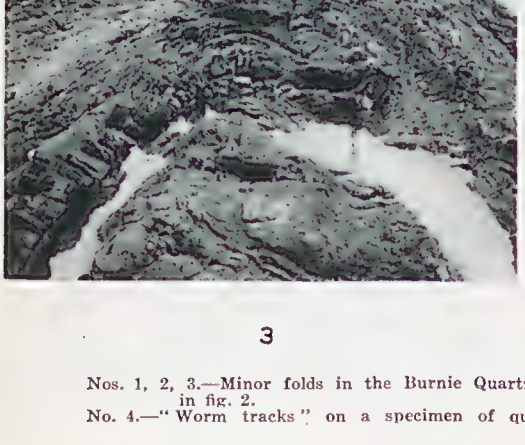

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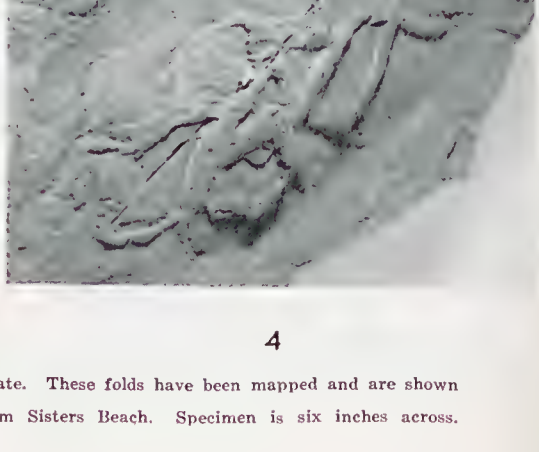

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Nos. 1, 2, 3.—Minor folds in the Burnie Quartzite and Slate. These folds have been mapped and are shown in fig. 2.
No. 4.—" Worm tracks " on a specimen of quartzite from Sisters Beach. Specimen is six inches across.

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PRECAMBRIAN ROCKS OF TASMANIA, PART II, MT. MARY AREA

By

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(With 5 Text Figures, 3 Plates and 1 Map)

ABSTRACT

The Mt. Mary area (S. lat. 42° 12′, long. 145°50′) is underlain almost entirely by rocks of Pre-Cambrian age, the exception being a small downfaulted block of Crotty (?) Sandstone, (Silurian). The Pre-Cambrian rocks are divided into three main groups. The oldest is the Joyce Group which consists of mica-garnet schists, quartzites and amphibolites. This is overlain unconformably by quartz schists, massive quartzites and phyllites of the Mary Group. Above these are quartzites, mica schists, garnet-mica schists and amphibolites of the Franklin Group. Igneous rocks are recognized as pre-metamorphic amphibolites (Older Basic Igneous Group) and post-metamorphic dolerites (Younger Basic Igneous Group).

The sediments are broadly folded into the Mary Anticline. Tight, recumbent drag folds are abundant and are shown by all formations. Cleavage or schistosity, generally parallel to the bedding, is well developed in phyllites and schists. A regular, regional lineation plunges flatly to the west and is cut by a sporadic lineation almost at right angles. Faulting is very abundant and makes the interpretation of the structure very difficult. Three sets of faults trend (in order of importance) at 120°, 10° and 60°-80°. The major faults are high angle reverse faults.

There is some degree of structural control of the physiography. All rivers are superimposed and two streams show maturity in their central reaches due to resistant quartzites forming local base levels. There is evidence of rejuvenation of some rivers.

Rocks of the Joyce and Franklin Groups are metamorphosed to garnet grade while the Mary Group is less altered. Selective metamorphism is demonstrated and is probably due to the favourable chemical and physical nature of the Joyce and Franklin Groups.

INTRODUCTION

The area described is located just south of the Lyell Highway and about 20 miles east of Queenstown. The mapping was carried out for the Hydro-Electric Commission by whose courtesy this report is published. Typical rock specimens were collected and are housed in the Geology Department of the University of Tasmania; the numbers in this report are those of the Geology Department rock catalogue.

The map is accurate as far as the distribution of *groups* is concerned but as it is very difficult to map *formations* because of the complexity of the faulting and soil or vegetation cover in critical areas, the degree of accuracy of the *formation* boundaries is only of reconnaissance standard.

ACKNOWLEDGEMENTS

The base map was prepared by the Hydro-Electric Commission. A preliminary photo-interpretation carried out by Professor S. Warren Carey revealed much of the major structure. A. Rundle, S. Makeham and I. Sanker assisted in the field mapping.

PREVIOUS LITERATURE

No previous work has been done in this area although the results of a traverse north of the Raglan Range were published by Ward (1908). A reconnaissance in the Loddon River and Jane River area was described by Ward (1909) and the knowledge of the Pre-Cambrian rocks of Tasmania summarized by Ward (1909). Brief surveys of the Jane River, Prince of Wales Range, Surveyor Range and Deception Range were described by Finucane and Blake (1933), Blake (1936) and Blake (1937).

PHYSIOGRAPHY

The area shows considerable relief and is quite rugged with altitudes over 3000 feet in places. The land surface is at a stage of early maturity and has been moulded probably entirely by fluviatile action. Mountain glaciers were active during the Pleistocene Epoch, only a few miles to the south at Frenchmans Cap, but there is no substantial evidence that any landform in the Mt. Mary area is the result of glaciation. Although the upper Joyce Creek superficially resembles a glacial valley it probably has not been glaciated.

There is a moderate relation between the physiography and the geology in that—

(*a*) certain groups or formations generally form ridges or hills while others are easily eroded and form valleys;
(*b*) faults and major joints frequently lie along valleys or saddles.

The highest point in the district is Raglan Bluff (3080 feet) on the eastern end of the Raglan Range. The Raglan Quartzite of the Franklin Group forms the backbone of this range.

For "Pre-Cambrian" read "Precambrian" throughout the paper.

Ward's Bluff (3020 feet) is the highest point of the arcuate ridge which is topographically (but not structurally) the south-easterly continuation of the Raglan Range. This high ridge is underlain by flatly dipping (25°) quartzites of the Mary Group; Plate I, No. 4 shows the form of this mountain with the massive quartzites forming prominent cliffs and the phyllites being easily eroded. Quartz schists form steep slopes and small cliffs.

Mount Mary (2940 feet) and Flat Bluff show similar geological controls. Both are capped by the quartz schist of the Mary Group which forms a cliffed top and this is underlain by soft, grey phyllite which forms the steep to moderate slopes around the north, west and south of the Mary Creek Plain.

There is a series of ridges in the south-western corner of the area which are formed of resistant quartzites and quartz schists of the Mary Group. These continue, increasing in height and steepness, to Philp's Peak and Frenchman's Cap.

The three major rivers in the area (Franklin, Joyce and Mary) are so independent of the geological structure that they are probably superimposed streams.

The Joyce Creek is youthful at its head and mouth but is quite mature in its central reaches where it has been held up by quartzites which form a local base level. The river begins on the very steep slopes of Raglan Bluff and then flattens off for two miles where it occupies a broad U-shaped valley. As mentioned previously, the shape of this valley at first suggests glaciation, but it is probably due to the fact that the stream flows along the strike of faulted phyllites and schists. The valley narrows about two miles east of Raglan Bluff and the river cuts a narrow steep gorge in the floor of the valley before swinging to the south. The next stretch (three miles) of the river is quite different in character. The gorge and rapids are replaced by a flat-bottomed valley with a narrow flood plain. The river meanders within the rather narrow confines of the valley and there are terraces (one at eight feet above the present river level) and cut-off meanders. The river falls about 700 feet in its first quarter-mile, 700 feet in its next three miles but only 100 feet in the next three miles. The last half-mile before the Joyce joins the Franklin is different again as the river straightens its path and cuts a steep gorge (6-800 feet deep) across the strike of the quartz schist and massive quartzite which act as the local base level.

The form of the Mary Creek is somewhat similar but shows some differences. The small creeks which run southwards across Flat Bluff, drop over the edge in small waterfalls and steep gullies and fall 1400 feet in the first half-mile. They then meander across the flat, button-grass covered Mary Creek Plain following two main paths. Here the creeks are about four feet deep and three feet wide with steep to vertical sides. There is 150 feet of fall in this one and a half mile stretch where the river has been held up by the resistant quartz-schist which caps Mount Mary. The high-level (1600 feet) Mary Creek Plain, plate I, No. 1, is quite a prominent physiographic feature of the area. The Mary Creek has reached a much more advanced state of maturity in its central tract than the Joyce Creek. The Joyce to the east, and the Maude to the west, have cut their valleys some 800 to 900 feet lower than this plain. The Mary Creek enters the quartzites to the south, straightens its course and descends approximately 1200 feet in the next two miles before it joins the Franklin River. About one mile north of the Franklin, it has a knife-cut gorge about five feet wide and 50 feet deep with practically vertical sides. Immediately south of this it plunges over a waterfall about 100 feet high.

The Franklin River is the largest watercourse in the area and flows from east to west across the southern portion. It is confined by a steep-sided, V-shaped valley which becomes a 400 foot gorge in parts. The sides usually slope at about 50° and are from 400 feet to 800 feet high with a cover of dense rain forest. The river displays a complex mountain tract with all the features of youth (steep valley, straight course, gorges and rapids). Some of its tributaries join through saw-cut gorges.

Two miles east of the junction of the Joyce and the Franklin are button-grass flats about 1000 feet above the present river level as shown in plate I, No. 2, while immediately east of the junction of the Mary and the Franklin is a small flat, about half-mile by quarter-mile which is about 150 feet above river level. This evidence suggests that there were at least two periods of still-stand when the river began to develop a broad valley tract in the softer rocks and that there has been later rejuvenation which caused the Franklin (and upper Joyce) to cut a narrow gorge below the level of the old valley.

The course of the Franklin is chiefly independent of the structure although it follows softer beds (phyllites) for distances of a quarter-mile or so before turning away. No evidence was found to suggest that the river follows a major fault zone, nor that it follows minor faults in parts.

Structural control of the rivers is not important although many minor streams show joint or fault control, e.g.:—

(*a*) There is a strong joint control of the streams on air photo 2487, Run 9, Lyell at one inch north-west of the photo-centre.

(*b*) The upper Joyce Creek is controlled by faults.

(*c*) The stream which flows to the east on air photo 2490, Run 9, Lyell, one and a half inches north of photo-centre lies along a fault. It joins another stream which flows along the western side of the Collingwood Range in a southerly direction, also along a fault.

(*d*) There is a fault control of the stream which flows east-south-east to join the Joyce Creek at the photo-centre of air photo 2632, Run 11, Lyell. This fault also controls the course of other streams.

Large landslides occur in several places and usually occur on steep slopes underlain by schists which weather to a clayey soil, e.g., in the upper Joyce Creek valley and south of Ward's Bluff.

Physiographic Expression of the Chief Rock Types

The Mary Group usually forms the highest points, e.g., Mount Mary, Ward's Bluff, Frenchman's Cap, and Philps Peak. The massive quartzites are most resistant and form the largest cliffs while the quartz schists are only a little more easily eroded and form steep slopes and smaller cliffs. The phyllites of this group are soft and form saddles or gullies.

The platy structure of the quartz schists frequently allows fritting by frost and wind to give pits and small caves.

The interbedded schists and quartzites of the Joyce Group are easily eroded and form the lower parts of the area, e.g., Mary Creek Plain and the country north of the Franklin in the south-east of the area.

The Franklin Group usually forms moderately high, rounded and rolling hills which are covered with a thick clayey soil supporting a dense cover of gum, bauera and tea-tree The joints frequently control the drainage pattern of the lesser streams. The thick quartzite which occurs just above the base of this group is resistant and forms the backbone of the Raglan Range.

STRATIGRAPHY

The area is chiefly underlain by rocks of probable Pre-Cambrian age. These have been divided into three groups, viz., Joyce Group (oldest), Mary Group and Franklin Group (youngest). These are chiefly sediments showing a low to medium grade of regional metamorphism together with lesser pre- and post-metamorphic basic intrusions. The total thickness is almost 20,000 feet. A little Crotty (?) Sandstone occurs in the north-east.

Crotty Sandstone

A wedge-shaped block of sandstone has been downfaulted into the Pre-Cambrian rocks in the north-eastern corner of the area. This rock is a soft, white, incoherent, sparsely fossiliferous sandstone which outcrops extremely poorly. The fossils remain merely as moulds and include unidentifiable spiriferids and brachiopods with abundant crinoid stems. Cubic cavities are common in some specimens and are probably moulds of pyrite crystals. Some specimens are strongly silicified to a massive quartzite and others show some mineralization. This formation is best observed along the curved track shown on air photo 2416, Run 8, Lyell and on the southern end of the button-grass area on air photo 2414, Run 8, Lyell, three inches south of the photo-centre.

The age of this formation cannot be properly determined because of the lack of diagnostic fossils and it is correlated with the Crotty Sandstone on lithological grounds. It belongs to the system of fault blocks containing Junee and Eldon Group rocks along the Lyell Highway in the vicinity of Bubb's Hill which is about five miles to the north-west.

Pre-Cambrian Rocks

The unfossiliferous, deformed and metamorphosed sediments which outcrop over the main part of the area are believed to be Pre-Cambrian in age. They unconformably underlie Ordovician rocks to the west at the Engineer Range and to the east at the Loddon Plains. They are lithologically similar to rocks which are unconformably below Middle Cambrian rocks elsewhere in the State.

Franklin Group

The Franklin Group was first recognized and named informally by Professor Carey. The first detailed field examination was made by J. B. McKellar and is defined by him (personal communication) as follows: it consists of those schists and quartzites lying below the Fincham Group and above the Mary Group and outcropping between the Franklin River and the Engineer Range west of Frenchman's Cap.

The rocks of the Raglan Range overlie the Mary Group unconformably (?) and appear to be structurally continuous with the Franklin Group which occurs on the other limb of the Mary Anticline. The group extends from the Raglan Range along the Cardigan River to the Collingwood River and the Lyell Highway, outcropping well between the 20 and 26-mile posts from Queenstown. The top of the group is not seen here and it is at least 5000 feet thick, and a tentative sequence is given below:

Top not visible	
Collingwood Schist	1000′+
Cardigan Schist and Quartzite	2000′
Raglan Quartzite	900′
Basal Schists	
Mica Schist	600′
Garnet Schist	600′
Bottom	

The uppermost phyllites of the Mary Group appears to grade upwards into fine-grained bi-mica schists which become increasingly garnetiferous upwards. This is followed by the Raglan Quartzite which is a prominent formation and could be a good marker horizon in this group. It is defined as that quartzite which occurs at Raglan Bluff, lying above the basal schists and below the Cardigan Schist. It is approximately 900 feet thick and has a distinctive lithology which is described on page 101. A similar formation occurs at the 26-mile post on the Lyell Highway as the northerly topographic (but not structural) continuation of the Collingwood Range.

Above the Raglan Quartzite, along the disused timber haulage track from Raglan Bluff down to the Cardigan River bridge is a considerable thickness (2000 feet?) of mica schists, garnet-mica schists, thin quartzites and amphibolites. This formation is named the Cardigan Schist and Quartzite.

The youngest formation in the area is named the Collingwood Schist. The type locality is along the Cardigan River just south of the bridge on the Lyell Highway but it outcrops well along the Highway in the area. There is at least 1000 feet and probably much more of mica schists characterized by albite porphyroblasts.

Lithologically the rocks of the Joyce Group strongly resemble those of the Franklin Group and these might well be correlated by their lithology. They are separated only on structural grounds.

Mary Group

This is defined as that group of quartz schists, massive quartzites and phyllites which occur on Mount Mary and in the area between the Mary Creek Plain and the Franklin River. It overlies the Joyce Group with probable unconformity and is overlain by the Franklin Group with possible unconformity. It is at least 8000 feet thick.

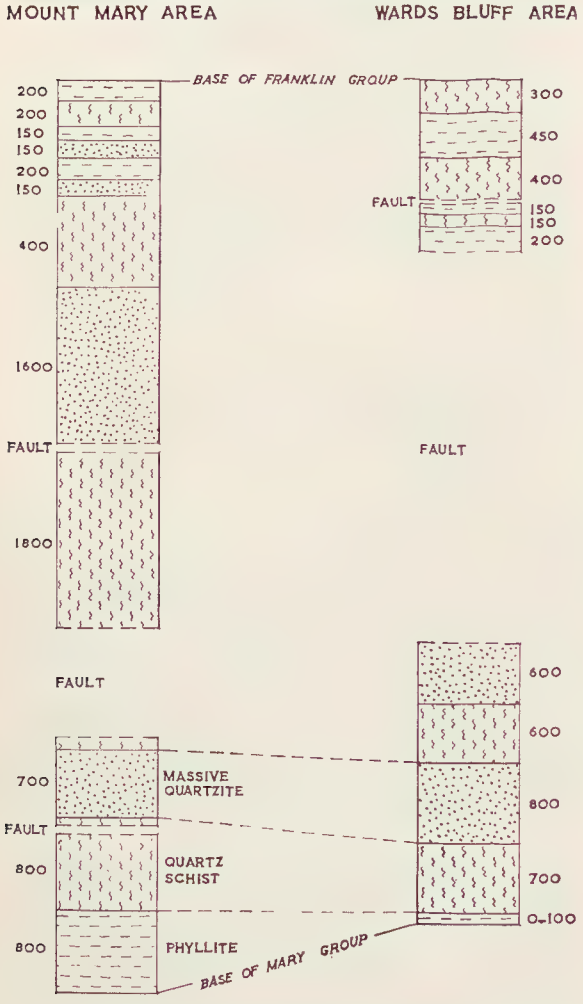


FIG. 1.—Stratigraphic sections through the Mary Group at Mt. Mary and Ward's Bluff.

Stratigraphic sections are shown in fig. 1 for the Mount Mary and Ward's Bluff areas. The lack of correspondence between two sections only three miles apart may be due to faulting, differential metamorphism or silicification, or to sedimentary facies change, and supports the contention given at the end of this section, viz., that any attempts at stratigraphy at a *formation* (as opposed to a *group*) level should be treated with the utmost caution at this stage.

Evidence is given in the petrology section that the phyllites may become silicified to quartz-schists some of which are massive enough to be regarded as massive quartzites. In general the three main rock types of this group (quartz-schist, massive quartzite and phyllite) may be mapped in restricted areas but formations cannot be traced for long distances. The phyllites are most irregular and thicken or thin out and disappear in short distances; thus it is believed that the phyllite in one section may be the time equivalent of a quartz-schist in another.

The quartz-schists are white, platy, mica-rich quartzites which are considerably contorted and crumpled. They have a well developed schistosity which is due to fine mica and some show two distinct lineations. They form bold, resistant outcrops and occupy the summits of many of the higher hills, e.g., Mount Mary and Flat Bluff.

The massive quartzites are white and thickly bedded. They are contorted and some specimens show a lineation while ripple marks and cross bedding are prominent in others. These rocks form steep cliffs and cap prominent hills such as Ward's Bluff.

The phyllites are soft, grey, lustrous rocks with a pronounced cleavage. Crenulation is prominent and two lineations may be present. Silicification has produced many quartz lenses, along the cleavage with boudinage structure, as shown in plate III, No. 3.

Beds of this group can be traced on the air photos from the Mount Mary area across to Philps Peak and Frenchman's Cap.

Joyce Group

This is defined as that group of schists, quartzites and amphibolites which outcrop along the middle reaches of the Joyce Creek and the country immediately to the east, and the Mary Creek Plain. It consists of approximately 5000 feet of garnet-muscovite schist, laminated muscovite quartzite, massive quartzite and diopside-amphibolite. It lies below the Mary Group but its lower limit is not known. The contact between the Joyce and Mary Groups is conformable on the limbs of the Mary Anticline; e.g., on the long spur which runs south from Ward's Bluff, garnet-mica schist dips at 10°-15° beneath quartz-schist of the Mary Group. The unconformable nature is shown at the Mary Creek Plain where the Joyce Group strikes at 75° and dips steeply north while the Mary Group strikes at 120° and dips at 10°-16° to the south.

It is not possible at this stage to give a sequence of formations in this group due to complexity of structure, lack of outcrop and dense vegetation cover.

Stratigraphic Principles

It must be emphasized that the stratigraphy outlined above must only be tentative for the following reasons:—

(i) Strong faulting and lack of outcrop combine to prevent the accurate determination of sequences and thicknesses of formations and groups. Strike faulting is common.

(ii) Rocks of identical lithology are repeated many times through the whole sequence and lithological correlation is not reliable. The structural complexity prevents the tracing of individual formations or even groups for any distance and this is the only reliable method of correlation.

(iii) The position above an unconformity is often useful as a correlation guide but in this area the sequence above the same unconformity differs in sections only a few miles apart.

(iv) Silicification of certain formations causes a very rapid and irregular change in lithology. It is suspected that a phyllite in one section is represented by a quartz schist in another. This implies that any detailed sequence measured in the Mary Group may be stratigraphically meaningless.

(v) Differential metamorphism of certain groups has resulted in the younger beds being more altered than older beds.

(vi) Tight, isoclinal folding causes thickening of individual formations, probably as much as 100 per cent so that there may be great errors made in taking the structural thickness to be the same as the stratigraphic thickness.

Unconformities

It is difficult to demonstrate conclusively an unconformity in this area, and in any of the adjacent parts which the author visited. It has been shown that the mildly altered Mary Group rests on the comparatively strongly altered Joyce Group, but this difference in degree of metamorphism and deformation cannot be taken as evidence of an unconformity between them, as the strongly altered Franklin Group rests on the Mary Group.

Faulting is so common, particularly parallel to the strike that discordance of strike or dip cannot be accepted as evidence of an unconformity.

On the western side of the Mary Creek Plain, the phyllites at the base of the Mary Group swing around the nose of the plunging Mary Anticline and are sharply discordant with the structure of the underlying Joyce Group. The form of the contact is such that faulting does not appear possible. This unconformity is not apparent a few miles east where the Joyce Group garnet schists dip conformably below the Mary Group. It is considered that there was not much folding between the deposition of these groups and that the contact is more in the nature of a disconformity between different phases of sedimentation.

It is considered that only regional mapping will reveal the presence of unconformities and that the classical evidence of a visible plane of discordance with the base of the upper group containing pebbles of the older, will not be found.

The section on fig. 1 show that the top of the Mary Group sequence differs in different places and this may indicate that there is not conformity between the Mary and Franklin Groups and that the latter overlaps the former. The abrupt thinning of the Mary Group around the nose of the Mary Anticline seems to be due to overlap by the Franklin Group and also suggests mild unconformity.

Igneous Rocks

Two periods of basic igneous intrusion are recognized. There are pre-metamorphic intrusives which lie among the Joyce and Franklin Groups and which have been regionally metamorphosed to amphibolites. These are probably related to the similar rocks at the Forth River, Port Davey, Whyte River and the Interview River dyke swarm. They will be referred to at present as the Older Basic Group, although this will only be a temporary name.

Post-metamorphic dolerites intrude the Franklin Group and petrographic examination reveals that they resemble the Cooee Dolerite with which they have been correlated (Spry 1956).

PETROLOGY

The origin of the metamorphic rocks presents a considerable problem which can only be solved by the systematic investigation of a wider area than is here described. The adjacent area, totalling some 500 square miles, has been mapped by geologists of the Tasmanian Hydro-Electric Commission and the petrology of these rocks will be published shortly. For this reason, the general petrographic nature of the rocks is given here but a discussion of the problems associated with their metamorphism will be deferred.

The Pre-Cambrian rocks in this area consist almost entirely of sediments (arenites and argillites) which have been regionally metamorphosed. The Joyce and Franklin Groups have reached garnet grade and contain garnetiferous schists, quartzites and amphibolites while the Mary Group would be related to chlorite grade. The Joyce and Franklin Groups are much more recrystallized and deformed than the Mary Group. Extending outside of this area it has been seen repeatedly that the most striking characteristic of the Pre-Cambrian rocks of Tasmania is the occurrence of interbedded strata showing differing degrees of metamorphism.

Joyce Group

This group consists chiefly of garnet-mica schist and mica-quartzite with a little pyroxene-amphibolite. The rocks are recrystallized and regionally metamorphosed to garnet grade (albite-epidote-amphibolite chloritoid-almandine sub facies of Turner (1951)) with the development of a new fabric. The rocks are thus similar to the Franklin Group but distinct from the Mary Group. This group lacks the hornblende amphibolite, and albite schists of the Franklin Group.

Garnet-mica schist is the most abundant member of this group. It is a grey, medium grained schistose rock consisting chiefly of muscovite and

quartz with porphyroblasts of garnet giving the rock a knotted appearance. Some specimens are very coarse and contain garnets and muscovite flakes a quarter-inch across. These schists occur on the long spur leading south from Ward's Bluff to the Franklin River, on the saddle on the east side of Mary Creek Plain and on the hill of the camp-site in the middle of that Plain.

Muscovite quartzite is a white, thinly bedded laminated quartzite containing abundant muscovite flakes giving a schistosity parallel to the bedding. It shows tight isoclinal folding in some localities with a lineation parallel to these fold axes. It outcrops sporadically across the southern parts of the Mary Creek Plain and on the saddle to the east, and is very prominent across the middle reaches of the Joyce Creek and to the west of Ward's Bluff.

A little pyroxene amphibolite (e.g., 6887) outcrops poorly on the Mary Creek Plain. It closely resembles the pyroxene amphibolite of the Franklin Group and is a member of the Older Basic Group.

Mary Group

This group differs considerably from the Joyce and Franklin Group in that it is dominantly siliceous and contains rocks which show only a low grade metamorphism and much less deformation. Three rock types only have been recognized and the group consists of a repetition of these.

Quartz schist (6226) is the most abundant rock in this group. It is a mica-rich quartzite which might equally well be called a schistose quartzite or a siliceous phyllite. It is a white, schistose rock with a characteristic platy appearance in outcrop. In some outcrops it is light-grey to yellow with a phyllitic appearance whereas in others it is less schistose and rather massive. The schistosity is parallel to the bedding which is usually contorted and tightly folded as shown in plate II, No. 2. In thin section it shows a fine, even texture with abundant tiny, parallel sericite flakes but with no obvious preferred orientation or elongation of the quartz grains.

Massive quartzites are common in this group. Some specimens, e.g., 6223, are fine grained, massive, well bedded rocks with cross bedding and ripple marks. The pure white colour of the outcrops is partly due to leaching of the surface as the rock is generally a rusty-brown within, due to weathering. Apart from a few folds such as shown in plate II, No. 1, these quartzites do not show much sign of contortion although some specimens (6251) show a distinct lineation. Thin sections show the rock to be generally a pure quartzite with only a little muscovite, tourmaline, zircon and iron ore. The least deformed specimens have a sutured texture with the quartz showing undulose extinction and "Boehme" lamellae and the mica with a random orientation. More strongly sheared rocks show granulation and a reduction in grain size of the quartz which tends to become elongated. These specimens show a preferred orientation of the mica and have a distinct lineation in the hand specimen.

The phyllites (e.g., 6222, 6227, 6239, 6241, 6253, 6309) are light to dark-grey rocks which are fine-grained, soft and lustrous with a strong cleavage. The cleavage is generally parallel to the bedding which is poorly developed. The phyllites are invariably crenulated with white quartz lenses along the cleavage as shown in plate III, No. 3. Thin sections show them to be fine-grained and rich in quartz and muscovite with accessory tourmaline, zircon, rutile, iron ore and rare chlorite. At least one cleavage is strongly developed and many specimens show two or even three. The replacement nature of the quartz lenses is clearly seen in thin sections.

It is possible that the quartz schists have been formed by silicification of the phyllites for the following reasons.

Phyllites are not persistent and disappear rapidly along the strike. The base of the Mary Group at Mount Mary is a thick phyllite but the base at Ward's Bluff shows a thin siliceous phyllite followed upwards by thick quartz schist. Stratigraphic sections in different parts of the area are difficult, if not impossible to match. Quartz schist passes into siliceous phyllite on the top of Flat Bluff. Replacement of phyllite by quartz schist is demonstrable on a microscopic scale.

The evidence against this hypothesis is not strong and is as follows:—

Adjacent beds of phyllite and quartz schist show sharp, non-gradational contacts. Nowhere in the field was a transition along the strike from typical phyllite to typical quartz schist found.

It is also possible that some of the massive quartzite may result from further silicification but this probably is not common.

Franklin Group

The rocks of this group are typical products of medium-grade regional metamorphism on a mixture of sandstones and shales with some pre-metamorphic basic intrusions. Muscovite and garnet rich schists are common with knotted albite-schists, garnet-gneisses, muscovite-quartzites and garnet-quartzites. Effects of deformation are shown by the strong schistosity of the schists and quartzites and the strong lineation of the quartzites.

The lowest bed of this group in this area is exposed in the saddle and valley immediately south of Raglan Bluff. It is a dark-grey, fine-grained, lustrous schist consisting chiefly of muscovite and quartz with a little biotite and garnet. Garnet becomes increasingly abundant upwards and just below the Raglan Quartzite is found a typical knotted garnet schist. The garnet is replaced by haematite in some mineralized specimens and by limonite in weathered specimens. Thin sections show that the rock consists chiefly of parallel laths of muscovite and elongated crystals of quartz with biotite, garnet, a little chlorite and accessory apatite, zircon and rutile. Albite is usually present as fresh twinned or untwinned crystals showing "rolled" structure.

There are thin beds of black lustrous phyllite which lack garnet and one unusual specimen is a garnet-chlorite schist. This is a contorted, schistose rock consisting of tiny chlorite flakes which are interlocking and undulating, with large (quarter-inch) porphyroblasts of garnet and accessory zircon and rutile.

Thin beds of garnet quartzite occur within this horizon and 6260 and 6264 are typical of these. These are dark-brown to black, fine-grained rocks with a banded and knotted texture. They consist chiefly of quartz and haematite. The iron ore clearly pseudomorphs garnet in some places but much of it has replaced quartz along intergranular contacts. There are patches of very fine-grained chloritic material and it appears that the quartz was first chloritized and them haematitized.

The next formation is the Raglan Quartzite which is well exposed at Raglan Bluff. It is a well-bedded to laminated, white to pale-grey, muscovite rich quartzite which shows contortion and isoclinal folding (from two inches to 200 feet across) and has a district cleavage parallel to the bedding and a pronounced lineation. Tourmaline needles occur abundantly in random orientation along the bedding plane-cleavage. Some varieties are rather massive and saccharoidal. The rock consists chiefly of quartz which is flattened and elongated, with parallel muscovite flakes, a little biotite and garnet (pseudomorphed by chlorite in some specimens) with accessory tourmaline, rutile, apatite and zircon.

The rocks in the Cardigan Schist and Quartzite do not differ apreciably from the above rocks individually. The formation is rich in knotted garnet-mica schists and mica quartzites.

Some varieties of the Collingwood Schist are characterized by the presence of porphyroblasts of albite. The typical albite schist is a light-coloured, schistose rock, rich in muscovite and containing porphyroblasts of albite which are generally about 5 mm. across but ranging up to 1 cm. in some coarse varieties. The albite gives the hand specimen a characteristic knotted appearance. Thin sections show that abundant mica wraps around the porphyroblasts of albite which are separated by quartz, muscovite, and biotite with accessory rutile and zircon. The albite is of two varieties. The large porphyroblasts are riddled with inclusions of quartz, are shattered and are twinned on combinations of the Albite and Carlsbad laws and are post-kinematic. The smaller albite crystals are lenticular in shape and display no twinning but have a strong rotational structure shown by "s" shaped trails of inclusions, and these are syn-kinematic.

A band of coarse gneiss which occurs along the Lyell Highway on both sides of the 21-mile post is characterized by containing garnets up to 1 cm. in diameter as well as streaks of pegmatitic material.

Older Basic Igneous Group

Two distinct varieties of amphibolite occur within the Joyce and Franklin Groups and these are regarded as being pre-metamorphic basic intrusives. Definite evidence of the intrusive nature of these rocks was not found in this area but J. B. McKellar and R. B. Mather (personal communication) have found intrusive amphibolites near the Franklin River. The two varieties are referred to as amphibolite and pyroxene-amphibolite.

Normal amphibolites are found in the Cardigan Schist and Quartzite of the Franklin Group in this area and are particularly well developed in the type area of this group according to McKellar (personal communication).

Typical is 6890 which is a fine, even grained but schistose dark-green rock. A thin section shows that it has an irregular texture and consists of green hornblende showing a moderate degree of preferred orientation together with albite and lesser garnet, biotite, calcite, zoisite, quartz and sphene. Some varieties are extremely rich in garnet and would be classed as garnet amphibolites.

Pyroxene-amphibolites occur in the Joyce Group and also among the Cardigan Schist and quartzite of the Franklin Group. The mineralogical composition is most peculiar and has not been recorded elsewhere. Chemical analysis shows that it has a composition similar to the normal amphibolites and the reason for the abnormal mineralogy is at present being investigated.

It is a medium to coarse-grained rock, even textured, heavy and green in colour. Pyroxene, garnet and amphibole are recognizable in the hand specimen with some difficulty but muscovite is prominent. It has a feeble banding, schistosity and lineation. A thin section shows that it is an even grained aggregate of garnet, diopside, pale actinolitic hornblende and muscovite with accessory rutile.

Younger Basic Igneous Group

A number of small dyke-like intrusions outcrop along Bradshaw's timber track between Mount Raglan and the huts to the west. The dolerite shows some alteration but is not regionally metamorphosed as are the garnet schists which it intrudes. These dolerites are related to the Cooee Dolerite (Spry, this volume) and details are given there.

Metamorphism

All the Pre-Cambrian rocks in this area are metamorphosed to some degree, but the intensity is so variable that it is evident that selective metamorphism has taken place. The Joyce and Franklin Groups show a higher grade of metamorphism and are more intensely deformed than the Mary Group.

The stratigraphic sequence in the western part of the Franklin Area appears to be as follows:—

Fincham Group
Franklin Group
Mary Group
Joyce Group

The Joyce Group belongs to the garnet zone and above this are the scarcely metamorphosed phyllites and quartzites of the Mary Group which belong to the chlorite zone. Next are the garnetiferous schists of the Franklin Group which belong to the garnet zone, overlain by the phyllites and quartzites (chlorite zone) of Mt. Fincham.

It can be seen that there is no relation between degree of metamorphism and age. In such terrain as this it is usually found that the youngest beds are least metamorphosed, or that less metomorphosed sediments are separated from schists by an unconformity. The only reasonable structural interpretation of this area indicates a stratigraphic succession in which slightly and moderately metamorphosed groups are interbedded.

The problems to be answered are:—

(1) Why have the Joyce and Franklin Groups apparently reached a higher grade of metamorphism than the rocks above, below and in between?

(2) Why do the Joyce and Franklin Groups show a better development of recrystallization, tectonic fabric and strong lineation?

As indicated earlier these problems will be discussed elsewhere.

STRUCTURE

The structure of the area is dominated by the broad Mary Anticline whose regional axis trends diagonally across the area from the south-eastern to the north-western corner. The oldest rocks (Joyce Group) occur as a core to the fold while the area is chiefly occupied by Mary Group rocks on the flanks. The Franklin Group outcrops in the north-east where it is folded into a small syncline and an anticline. Faults are common throughout the area and most important is a set striking at 120°. Two of these are high angle thrusts dipping inwards towards the axis of the Mary Anticline. Another important set is at right angles to these and strikes at 0-20°. Cleavage is well developed parallel to the bedding in most rocks and the mica schists are strongly schistose. There is a regular regional lineation which plunges flatly to the west. A small wedge-shaped fault block containing Crotty Sandstone occurs in the north-east of the area. The age of the folding and faulting is not known but it is considered that the major folding is both Pre-Cambrian and Tabberabberan although the metamorphism was Pre-Cambrian.

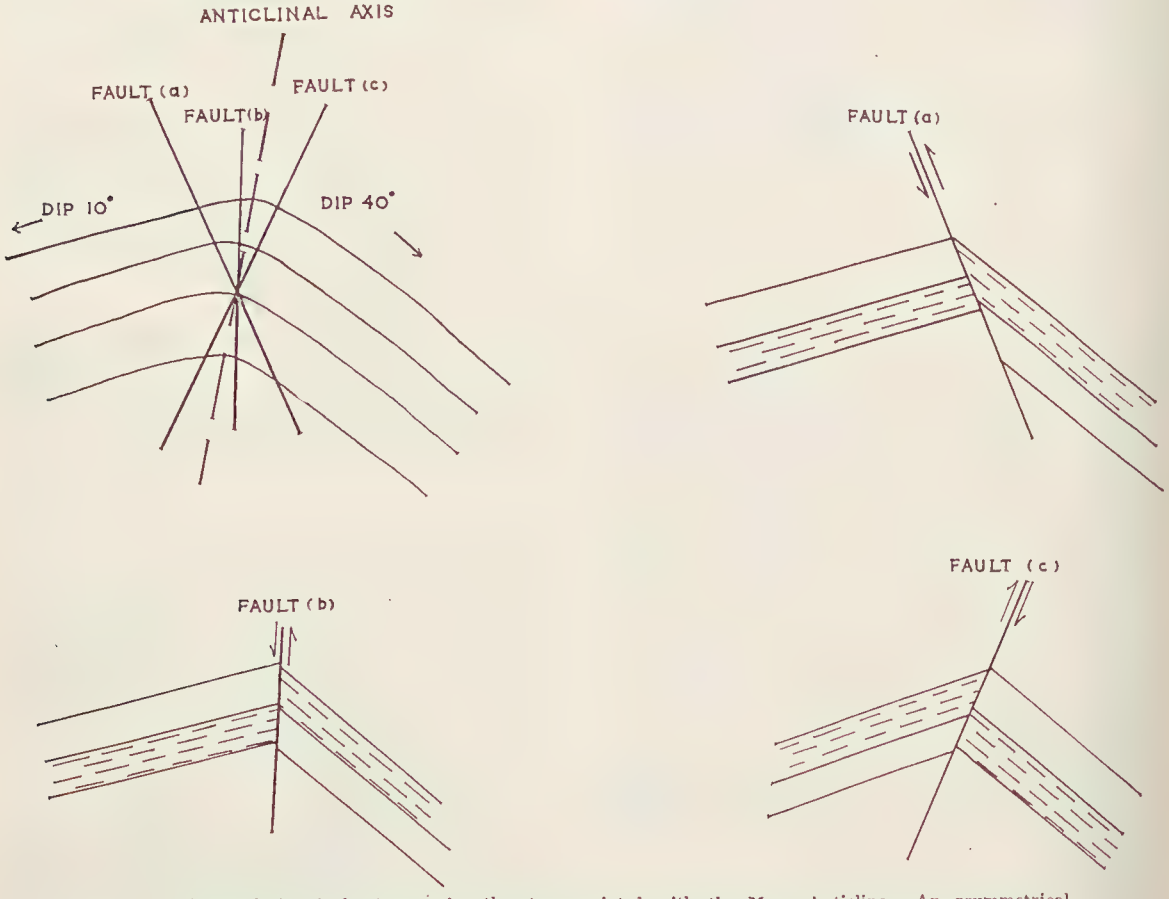
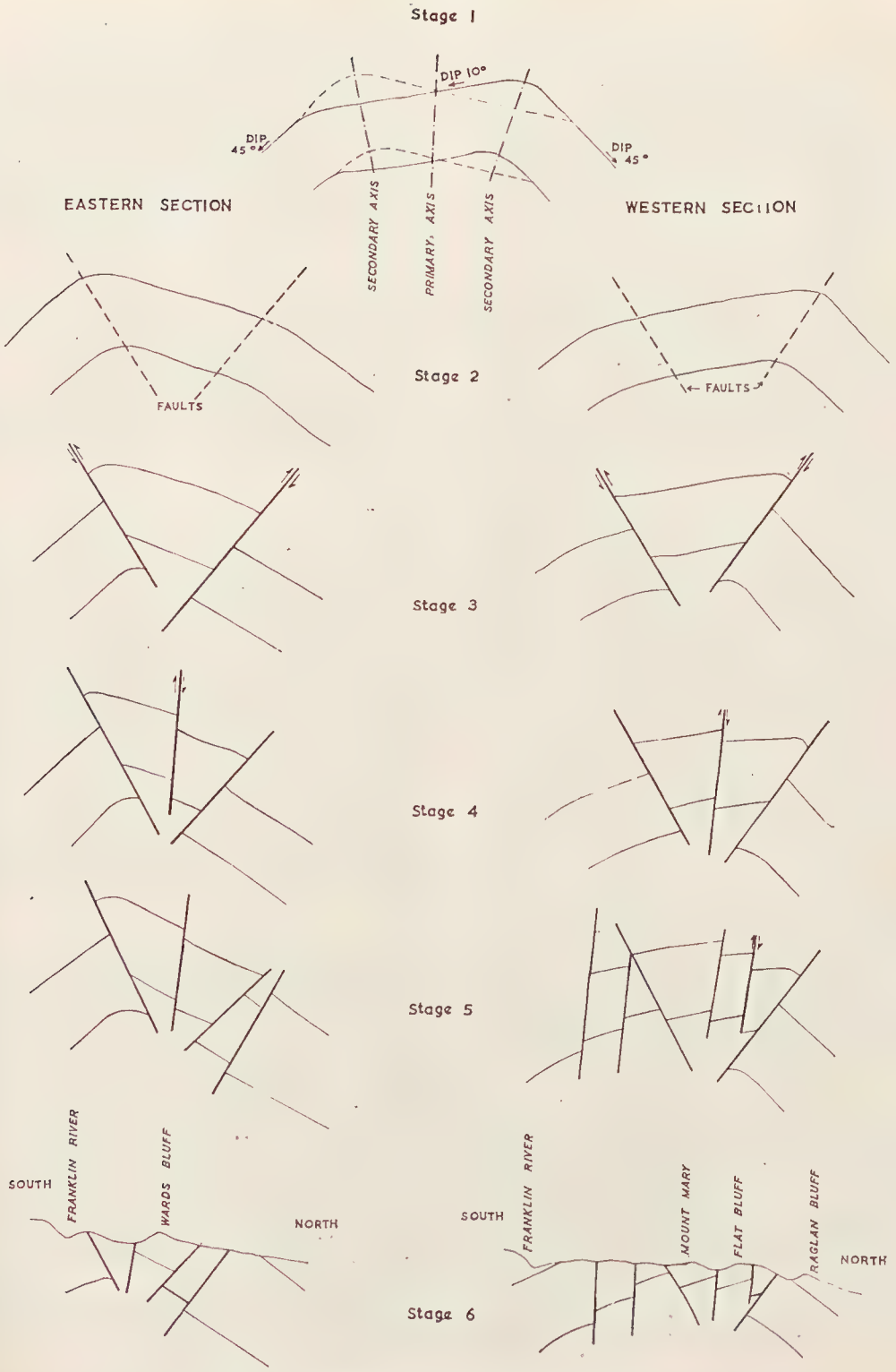


FIG. 2.—An analysis of the two major thrusts associated with the Mary Anticline. An asymmetrical anticline may be cut by three alternative faults (*a*), (*b*) and (*c*). Each of these could fault out the flat crest and bring beds of different ages, dipping in opposite directions, into contact. Only alternative (*c*) matches the field evidence, thus the faults are interpreted as being high angle thrusts, dipping towards the flatter dipping beds.



STRUCTURAL EVOLUTION OF THE MARY ANTICLINE

FIG. 3.—The structural evolution of the Mary Anticline taken stage by stage. The two sections are taken at right angles to the fold axis through Mt. Mary and Ward's Bluff. For more details see fig. 4.

Mary Anticline

The major axis of this symmetrical anticline runs from the north-west corner to the south-east corner of the area in a direction 300°. In the north-west the axis plunges flatly west. The fold appears simple on a regional view but in detail is quite complex due to faulting. The axis appears to lie between Flat Bluff and Raglan Bluff where Franklin Group rocks dipping at 40° to the north are faulted against Mary Group rocks dipping at 10° to the south. The axis appears also to be south of Ward's Bluff where Joyce Group schist dipping north at 12° is faulted against Mary Group quartz-schist dipping south at 40°. Thus faulting along the axis has removed the horizontal crestal zone but more important is the appearance of the axis being displaced two miles at a cross fault. This fault then appears to be a right-handed transcurrent fault but observations in the field and inspection of the air photos show that it does not continue to the south. Also this fault displaces the base of the Franklin Group north of the Joyce Creek in a left-handed sense.

An explanation for the apparent displacement of the axis is given in fig. 2. It is considered that two puckers were developed along the main axial zone concurrently with a pivotal fault perpendicular to the axis as shown in plate III. Two steep reverse faults formed along these minor axes and movement along these raised the central block and faulted out the horizontal zone of the fault. Fig. 3 shows why only a steep reverse fault could bring the flatter older beds up against the younger steeper beds. Later vertical normal faults striking in the same direction caused additional complication. There appears to have been further movement on a northern extension of the pivotal fault, accounting for the displacement of the base of the Franklin Group, just north of the Joyce Creek.

The Mary Anticline is a minor anticline lying between synclines of the Loddon and King Rivers where Palaezoic rocks are down-folded into the Pre-Cambrian.

There is a faulted syncline which runs from the Lyell Highway south along the western side of the Collingwood Range. It cuts across the north-eastern corner of the area where a wedge of Crotty (?) Sandstone has been faulted down into the axial zone. In this area there are rocks of the Franklin Group on each side of the axis, but to the south-east quartz schists of the Mary Group appear along the faulted axis, thus the fold appears to be plunging to the north.

Minor Folds

Most formations show tight, recumbent, isoclinal folds and crenulation. These folds are commonly a foot or so across as in plate II, but may be of a microscopic scale or up to several hundred feet across. These folds are associated with a period of metamorphism and deformation and do not seem to be related to the major folds. They are seen to be incongruent flow folds and not drag fold where they—

(*a*) indicate that a bed is overturned in one place but right way up only a foot away along the strike.

(*b*) indicate that a bed is overturned while the regional structure indicates that it is not.

The pronounced crenulation shown particularly by the phyllites of the Mary Group appears to be independent of this drag folding as the lineation which is parallel to the axes of the drag folds if folded by the crenulation. Some zones of crenulation indicate tiny transcurrent movements. Probably the crenulation is related to the folding of the Tabberabberan while the isoclinal folding and lineation are related to the earlier Pre-Cambrian orogeny which produced the metamorphism.

Cleavage

Only the massive quartzites of the Mary Group lack the cleavage which is developed parallel to the bedding of phyllites, quartz schists, mica schists and mica-quartzites.

Cleavage and bedding are clearly discordant in the phyllite which outcrops in the bed of the Franklin River one mile upstream from the mouth of the Mary Creek.

Lineation

A number of different kinds of lineation are developed in this area but these may be divided into two genetic groups. There is an older, general lineation which is of considerable structural significance together with a later superficial lineation.

The fine crenulation in phyllites and mica schists, ribbing in quartzites, parallelism of amphibole laths in amphibolites and of muscovite flakes in mica quartzite are all remarkably constant in direction throughout the area. This lineation generally plunges at 10° in a direction 300°, although some plunge as steeply as 45° west, while others plunge 2-5° to the east although still on the same strike. This lineation is parallel to the axes of the isoclinal folds and also with the axis of Mary Anticline. Lineation may become an important tool in regional mapping as it is probably parallel to the axis of Pre-Cambrian but not Tabberabberan folds and thus might be useful for distinguishing between them.

The massive quartzites of the Mary Group show little deformation and some specimens show no appreciable recrystallization or tectonite fabric. Cross bedding and ripple marks may be prominent in some rocks which are seen under the microscope to be severely deformed. In some cases it is difficult to ascertain whether the ripples are of sedimentary or tectonic origin but the evidence for them being of a primary depositional origin is as follows:—

(*a*) Some specimens show the typical cuspate form of the stationary wave ripple.

(*b*) In some outcrops the ripples are not parallel in beds a few feet apart.

(*c*) Some specimens show ripple marks which have been deformed by a corrugation at an angle to them.

The massive quartzites show a very pronounced corrugation where the ripple marks happen to have been parallel to the lineation direction.

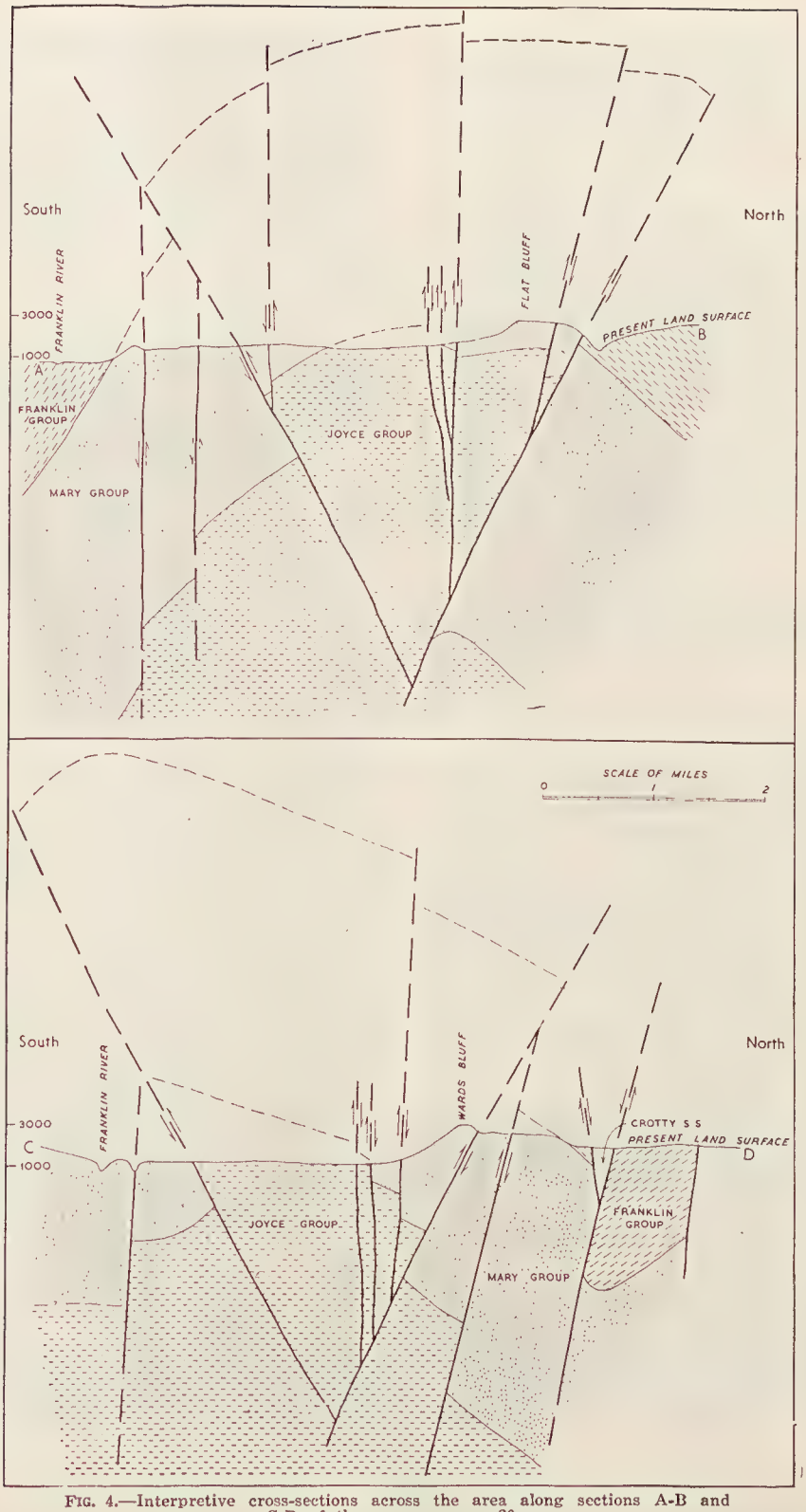


FIG. 4.—Interpretive cross-sections across the area along sections A-B and C-D of the map on page 20.

Joints

All rocks in the area are jointed to some degree but apart from the "a-c" joints normal to the lineation, no joints which could be related to a major structure were found.

Faults

As in all areas of Pre-Cambrian rocks so far studied in Tasmania, faulting is abundant. The presence of several distinct sets of faults makes the detailed structure so complex as to be practically insoluble. In most cases the amount of (or even the direction of) displacement can not be determined because details of the stratigraphic sequence are not known.

Most of the faults shown on the map were recognized first on the air photos because of their topographic expression and many of these remain unconfirmed because of the lack of recognisable displacement. Most difficult to prove are the major strike faults which show no displacement in plan and which can only be proven if the stratigraphy is known in detail. Strike faulting appears to be very common in the Pre-Cambrian rocks in Tasmania.

Minor structures such as contortion, drag dip, slickensides and crush breccias are of limited use in proving the presence of faults for the following reasons.

(*a*) All rocks in the area are so contorted that contortion and drag in a fault zone is not often recognizable with certainty.

(*b*) Slickensides are abundant and it is not possible to recognise whether they occur on major faults or on the innumerable small faults. A further difficulty is that some slickensided surfaces show several sets of striations at various angles (even 90°) to each other.

(*c*) Excellent crush breccias are found in the quartzites of the Raglan Range and Ward's Bluff. In the latter locality lines of breccia resist erosion and stand up like walls of coarse concrete. As far as can be determined, crush breccias are only developed on the small faults.

(*d*) Where the major faults can be observed there is no outstanding contortion, drag, slickensiding or brecciation.

Strike faults frequently separate beds which dip in opposite directions or the same direction but in different amounts and may thus resemble an unconformity. This aspect was discussed in the stratigraphy section.

A number of different sets of parallel faults are recognisable but only the more important ones are shown on the map.

(*a*) One group consists of a considerable number of faults of small throw striking at 350° at Flat Bluff but varying up to 35° at Ward's Bluff. They are vertical normal faults with throws from 10 feet to 100 feet. These are recognisable only in areas of flat-lying sediments where displacements of a contact between two formations may be followed. These faults, although abundant, are not of great importance and no attempt was made to map them over the whole area.

(*b*) There is a group of faults trending between 60° and 80°, which have considerable displacements although the exact magnitude cannot be determined because of lack of knowledge of the direction of movement. They are oblique to the strike and are therefore easily recognisable. The large displacements and occasional drag visible in plan suggest that they might be transcurrent faults although it is more likely that they are vertical, normal faults as they do not persist for more than two miles.

(*c*) The most important are those strike faults trending at 120°. Two of these are steep reverse faults associated with the development of the Mary Anticline but the others appear to be vertical, normal faults related to those which affect the Eldon Group near Bubb's Hill. Thus there may be two genetically separate sets parallel to this direction; one compressional, the other tensional. Both the thrusts and the normal faults displaced the Eldon Group and are Tabberabban. These faults are persistent, two extending across the full width of the area mapped, thus being at least six miles long. Regional studies suggest that one of these faults continues off to the east and passes south of the East Loddon River while another heads off towards the King River Valley to the west. The majority of the normal faults in this direction have downthrows to the north. The related faults near Bubb's Hill lower the Eldon down into a graben parallel to the Lyell Highway. In the north-eastern corner of this area a wedge of Crotty (?) Sandstone has been downfaulted into the Pre-Cambrian by faults which strike at 130° and 150° but which nevertheless probably belong to this set. Faults of this set abut against, are displaced by, and themselves displace the set of faults striking meridionally and thus these two sets of faults at right angles are probably conjugate.

Age of the Orogenies

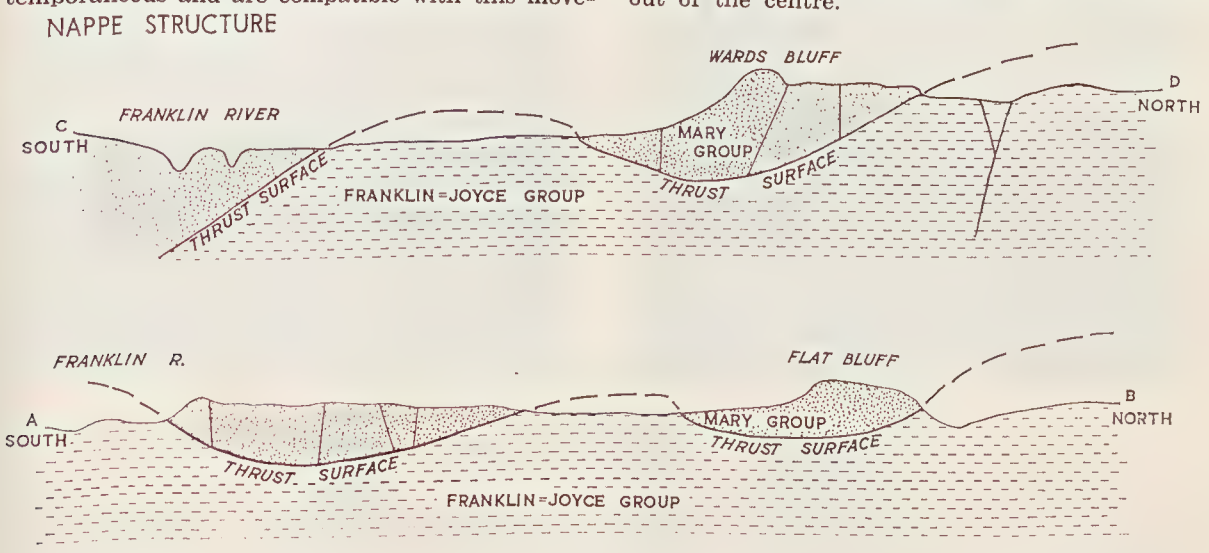
The Ordovician to Devonian sediments in this area are folded and as the Pre-Cambrian rocks are similarly folded and there is no strong unconformity, it is probable that a considerable part of the folding is Tabberabberan.

During the Pre-Cambrian orogeny the sediments were under a considerable load and were first subjected to powerful horizontal forces acting in a couple which may be regarded as overthrust to the south and underthrust to the north. This resulted in gently folded, mildly (but selectively) metamorphosed beds with a schistosity parallel to the bedding and a regional lineation.

Erosion to a flat surface produced a basement on which the Junee and Eldon were deposited. The Pre-Cambrian folding was broad and gentle. The Tabberabberan orogeny folded both Palaeozoic and Pre-Cambrian rocks thus superimposing later folds on the earlier ones but did not produce sharp structural unconformities. The Mary Anticline was initiated during the Frenchman Orogeny because the lineation which was formed during regional

metamorphism is parallel to the axis of the fold. However, during the Tabberabberan the folding was repeated, but this time was accompanied by faulting. The two thrusts are clearly related to the folding and it appears that the anticline was formed by horizontal compression combined with an upwards movement of a block along the centre. The normal faults parallel to the thrusts appear to be contemporaneous and are compatible with this movement. These relations are shown in detail in figs. 3 and 4.

There does not seem to be any Tertiary or Jurassic faulting present. No faults show the topographic expression of Tertiary faults and the depression along the Lyell Highway in the Nelson and Collingwood River valleys is probably an old graben with the softer Palaeozoic rocks weathered out of the centre.



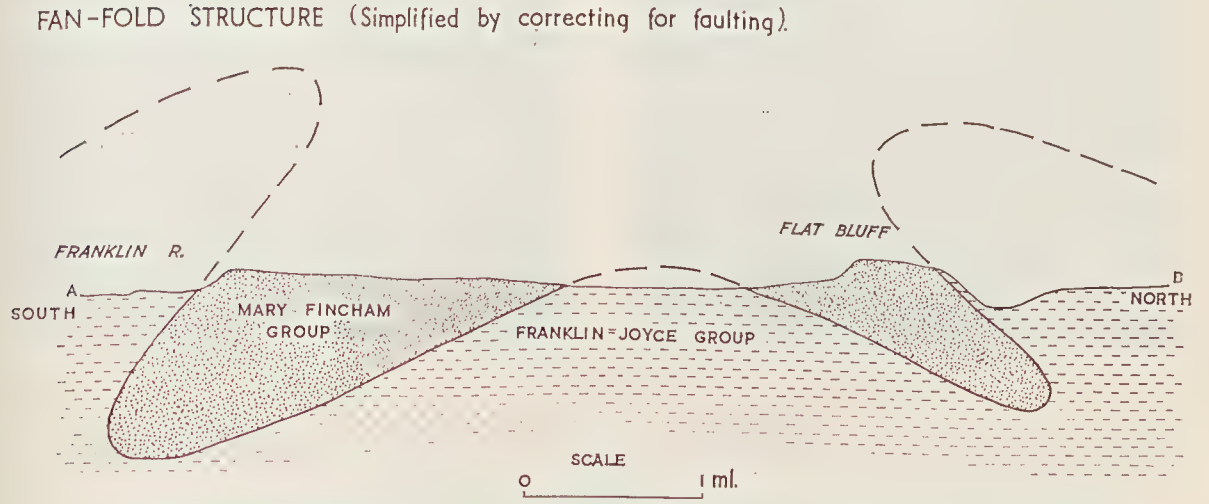


FIG. 5.—The lithological similarity of the Joyce and Franklin Groups suggest that they might be stratigraphically identical. The three sections show two alternative structural explanations on the basis of large scale overthrusting or overturning. While these explanations seem possible in cross-sections, the regional structure disproves them. This will be shown in detail in a paper now in preparation.

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LOCALITY INDEX

	Quadrangle	S. Lat.	E. Long.
Bubb's Hill	Lyell 58	42° 7′	145° 45′
Cardigan River	Lyell 58	42° 8′	145° 49′
Collingwood Range	Lyell 58	42° 10′	145° 53′
Collingwood River	Lyell 58	42° 10′	145° 44′
Deception Range	Lyell 58	42° 22′	145° 50′
Engineer Range	Pillinger 65	42° 18′	145° 44′
Flat Fluff	Lyell 58	42° 10′	145° 48′
Forth River	Sheffield 37 Middlesex 45	41° 25′	146° 15′
Franklin River	St. Clair 52 Pillinger 65	42° 22′	145° 46′
Frenchman's Cap	Pillinger 65	42° 17′	145° 50′
Jane River	Pillinger	42° 28′	145° 50′
Joyce Creek	Lyell 58	42° 10′	145° 48′
King River	Strahan 57 Lyell 58	42° 10′	145° 30′
Loddon Plains	Pillinger 65	42° 17′	145° 57′
Mary Creek	Lyell 58	42° 12′	145° 48′
Mary Creek Plain	Lyell 58	42° 10′	145° 48′
Maude Creek	Lyell 58	42° 12′	145° 47′
Mount Mary	Lyell 58	42° 12′	145° 50′
Philp's Peak	Pillinger 65	42° 17′	145° 52′
Port Davey	Davey 91	43° 20′	145° 55′
Prince of Wales Range	King William 66 Huntley 73	42° 30′	146° 31′
Queenstown	Lyell 58	42° 5′	145° 33′
Raglan Bluff	Lyell 58	42° 9′	145° 47′
Raglan Range	Lyell 58	42° 8′	145° 46′
Surveyor Range	Pillinger 65	42° 24′	145° 52′
Tim Shea (Mt. Stephens)	Huntley 73	42° 43′	146° 29′
Ward's Bluff	Lyell 58	42° 11′	145° 52′
Whyte River	Magnet Corinna	41° 30′	145° 14′

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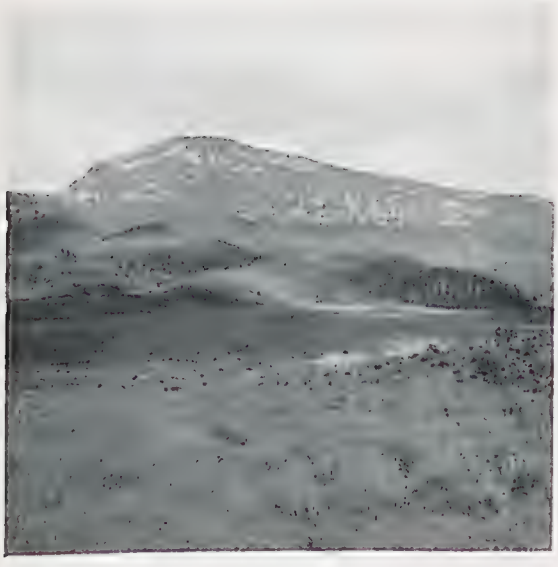

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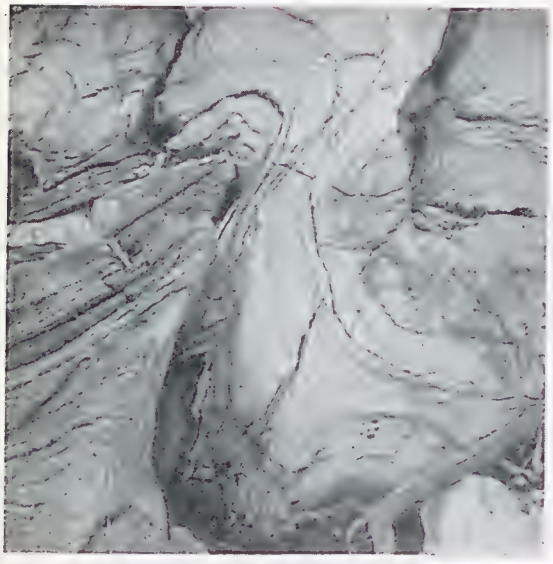
4

No. 1.—Mount Mary from the north-east. The high level Mary Creek Plain stands at the foot of Mount Mary, and the Joyce Creek cuts well below this in the foreground.

No. 2.—Across the Franklin River to Frenchman's Cap from near Wards Bluff. The high level river flats are visible in the foreground.

No. 3.—Mount Mary from Mary Creek Plain. Basal phyllite and quartz schist of the Mary Group overlie the Joyce Group which outcrops on the plain.

No. 4.—Ward's Bluff from the south. Massive quartzites interbedded with quartz schist at the base of the Mary Group.



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No. 1.—Folds in massive quartzite of the Mary Group, south-east of Ward's Bluff.
No. 2.—Recumbent isoclinal folds in quartz schist o the Mary Group.
No. 3.—Raglan Bluff from the east. It stands at the head of Joyce Creek which runs east. Franklin Group dips steeply north on the right-hand side of the photo and is separated by a major thrust fault from the Joyce Group dipping flatly south on the left.
No. 4.—Folding and overthrust faulting in quartzite of the Raglan Bluff. The area shown is about 50 yards across.

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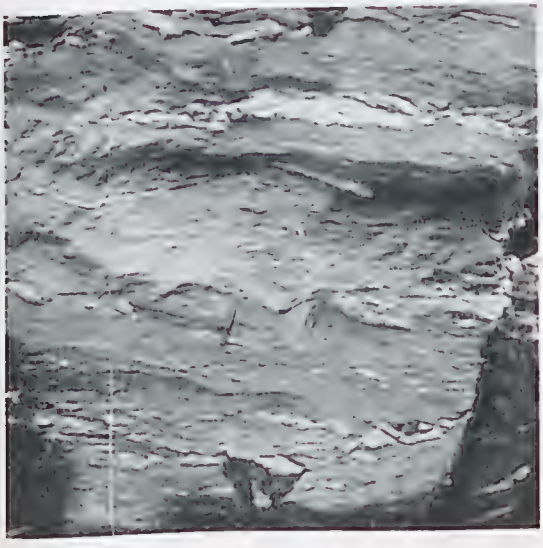

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4

No. 1.—Steep thrust fault in the Mary Group in the upper Joyce Creek.
No. 2.—Strong lineation (ribbing) in Franklin Group quartzite of Raglan Bluff with "*a-c*" joints normal to the lineation.
No. 3.—The basal phyllite of the Mary Group at the base of Flat Bluff. Silicification has produced quartz lenses along the schistosity; typical corrugation is visible.
No. 4.—Photograph of a plasticene model of the Mary Anticline showing the secondary folds and the hinge fault developed on the crest, with the positions of the major thrust faults marked. Sections across this structure are shown in fig. 3.

GEOLOGY OF TASMANIA
ONE INCH SERIES – UNIVERSITY OF TASMANIA, GEOLOGY DEPT

MT. MARY

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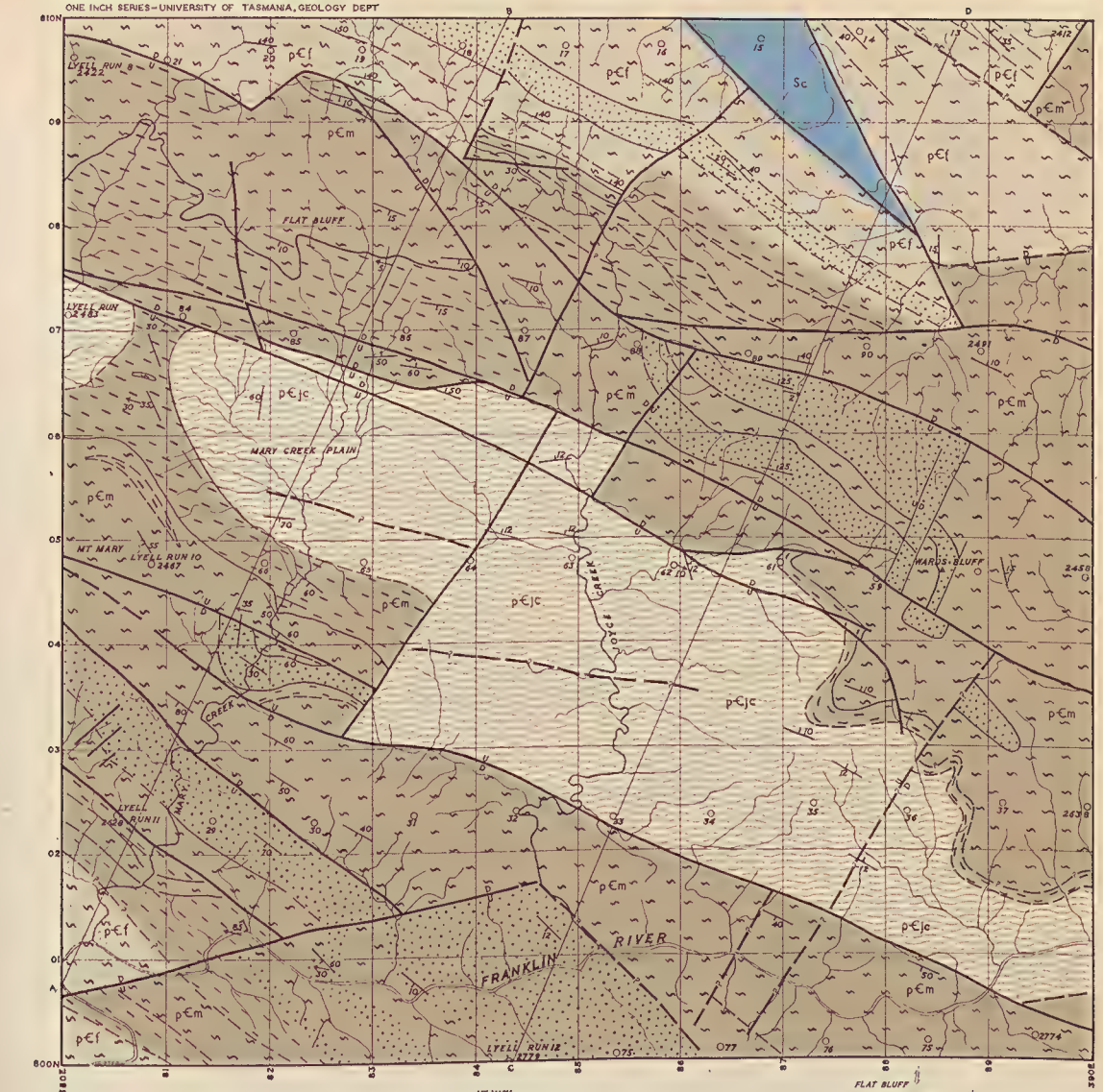

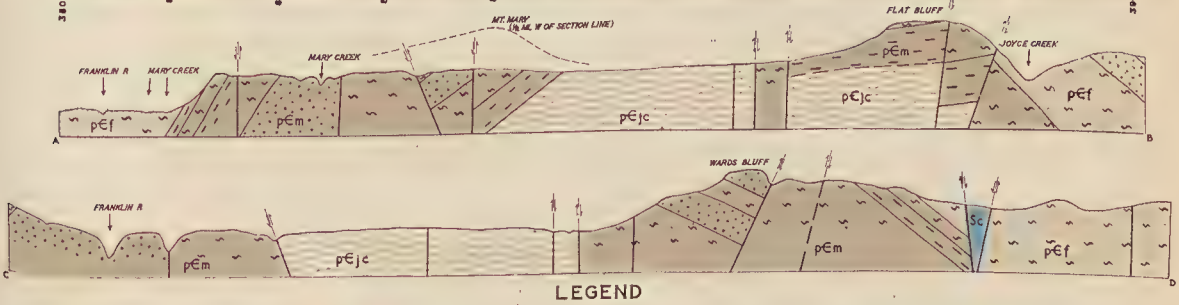

LEGEND

- FAULT
- FAULT POSITION APPROXIMATE
- FAULT INFERRED
- FORMATION BOUNDARY
- FORMATION BOUNDARY APPROXIMATE
- FORMATION BOUNDARY INFERRED
- STRIKE AND DIP
- DIRECTION AND PLUNGE OF LINEATION
- STRIKE AND DIP OF CLEAVAGE

Silurian

- Sc — CROTTY SANDSTONE

Precambrian

FRANKLIN GROUP

- pEf — SCHISTS & QUARTZITE
- pEf — QUARTZITE

MARY GROUP

- pEm — PHYLLITE
- pEm — MASSIVE QUARTZITE
- pEm — QUARTZ SCHIST

- pEjc — JOYCE GROUP

Compilation from Aerial Photographs.
Trigonometric Station Control by courtesy Hydro-Electric Commission.
Origin of Co-ordinates 400,000 yds. West and 1,800,000 yds South of True Origin of Zone 7

MAPPED AND COMPILED BY A.H. SPRY. 1955

KEY MAP SHOWING MAGNETIC DECLINATIONS
SECULAR VARIATION 7MINS PER ANNUM

SCALE
2 MILES
10,000 FEET

GEOLOGY OF THE MT. MARY AREA

1. BIBLIOGRAPHY:

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2. STRATIGRAPHIC TABLE:

AGE	GROUP	FORMATION	LITHOLOGY	THICKNESS
		TABBERABBERAN OROGENY		
Silurian	Eldon	Crotty	Sandstone	200'?
		TYENNAN OROGENY		
	Younger Basic Igneous Rocks		Dolerites	
		OROGENY WITH REGIONAL METAMORPHISM		
	Older Basic Igneous Rocks		Amphibolites	
	Franklin	Cardigan	Schist (mica, garnet) and Quartzite	2000'?
		Raglan	Quartzite	900'
			Schists	1200'
Precambrian		**MINOR UNCONFORMITY (?)**		
	Mary		Quartz schists, massive quartzites, phyllites	10,000'
		MINOR UNCONFORMITY (?)		
	Joyce		Mica and garnet schists	5000'(?)

3. LOCALITIES OF SPECIAL INTEREST:

Major thrust fault between Mary and Franklin Groups	E382000.N809300
Minor thrust fault	E384600.N808600
Minor isoclinal folds	E380700.N805200
Ripple marks	E381600.N804000
Pyroxene amphibolite	E382600.N806200

THE GEOLOGY OF THE SANDFLY-OYSTER COVE AREAS, TASMANIA

By

T. H. Rodger

Communicated by Professor S. Warren Carey

(With 2 Maps)

ABSTRACT

The Sandfly-Oyster Cove areas consist of Permian and Triassic sediments which have been widely intruded by dolerite in the form of sills and dykes. The sills are so extensive that it appears unlikely that any of the sedimentary exposures have been left in their original stratigraphical positions. Syenite dykes occur in the south of the area, and two basalt outcrops have been mapped.

INTRODUCTION

The mapped area is bounded by co-ordinates 500,000 yards E. to 510,000 yards E., and 690,000 yards N. to 710,000 yards N. on sheet No. 6 of the 4-mile State map of Tasmania. Maps were compiled from aerial photographs by the slotted template method, controlled by ground survey of the Trigonometrical Stations shown on the maps. Geological data were plotted directly on to aerial photographs in the field.

I would like to thank Professor S. W. Carey for general guidance, helpful criticism and for having made available many of the resources of the Geology Department, University of Tasmania. To Miss B. Scott, for help with several petrological problems, and to Mr. M. R. Banks who was an untiring critic and guide throughout the work, I also express my appreciation.

PHYSIOGRAPHY

The area is rugged with a juvenile topography. Elevations range from just above sea level to nearly 2500 feet, with much of the area over 1000 feet. A watershed trending north-south extends through the western section of the area from Nicholls Rivulet through the Snug Plain and Kaoota to Herring Back. Drainage from this high ground is to the east, west and south. The many small streams are swiftly flowing, with rapids and waterfalls both very common.

Exposures in the area are generally poor. In the sediments cliffs are not uncommon, but these are often too steep and high to be climbed. The steeper slopes of the area are covered with thick dolerite talus and scrub; open and undulating country is under cultivation. The boundaries between dolerite and underlying sedimentary rocks are completely obscured by the more resistant dolerite scree.

STRATIGRAPHY

Due to widespread injection of dolerite in the form of sills and dykes the sediments have been so broken that only one formation was seen as a whole unit. The heat accompanying the intrusions has so altered the sediments on the contacts that in many places where sediments are visible, they are completely altered in character. These altered sediments have resisted erosion and so form a very large proportion of the outcrops.

The sediments found in the Sandfly-Oyster Cove Areas are listed below stratigraphically:

Quaternary System:
- Alluvium

Triassic System:
- Feldspathic Sandstone
- Knocklofty Sandstone and Shale

Permian System:
- Ferntree Mudstone
- Woodbridge Glacial Formation
- Grange Mudstone

PERMIAN SYSTEM

Grange Mudstone

Outcrops occur only in the Sandfly area; the most prominent extends north and south from Allens Rivulet and another lies west of Snug. Rocks in the northern part of the first, and in the whole of the second area mentioned above have been baked by the intrusive dolerite and have lost their true sedimentary character. At Allens Rivulet there are high cliffs, not easy to examine, which closely resemble the type section at the Grange Quarry. The upper and lower limits of the mudstone were not seen in the area.

The Grange Mudstone is typically a hard rhythmically bedded siliceous mudstone which fractures along the bedding planes. The rock is usually creamy-yellow in colour, but may be as dark as purple. Bedding is pronounced and is marked by weathered fossil bands. The average grain size is 0·01 mm., with grains larger than 0·02 mm. comprising less than 10 per cent of the rock. The average size of the larger grains is 0·1 mm., and the maximum grain size, 2 mm. The grains are tabular or prolate in equal proportions, and the degree of rounding varies from sub-rounded to angular with the largest proportion in the sub-angular class.

The rock is made up of fossil fragments and granular material of which 90 per cent is quartz. Feldspar makes up the remaining 10 per cent, half being orthoclase and the remainder undetermined plagioclase. Sandy horizons are known from the Grange Mudstone, but were not found in any of the exposures examined. The following heavy minerals were present in representative samples which were crushed and separated: haematite, ilmenite, muscovite, zircon, tourmaline and apatite, but of these only haematite, which is of the earthy variety, is common. Those grains not fractured in crushing all showed some rounding.

The mudstone is extremely fossiliferous throughout most of the sequence and abundant *Fenestella sp., Protoretepora sp.* and *Stenopora sp.* give the rock its laminated appearance. Also common are *Strophalosia sp., Terrakea fragile, Spirifer convoluta* and *Martiniopsis sp.*

Well-rounded pebbles are common throughout the formation and have a maximum diameter of 4 cm. The larger pebbles are all of quartzite though small pebbles of quartz less than 2 cm. in diameter are common.

Dolerite intrusions have effected the Grange Mudstone more than other Permian formations, because of the fine rhythmic bedding which allows easy access to the sediment for many thin sills of intrusive rock. It is suggested that this multiple injection has caused the extensive baking of the mudstone over such a large area. The absence of distortion of the fossils and the lack of crystal orientation in these indurated rocks suggests that alteration has been due to heat with relatively little pressure.

Woodbridge Glacial Formation

This formation, which lies conformably below the Ferntree Mudstone, presents the most varied lithology of the Permian sediments. The base of the formation was not seen, but the greatest vertical section of the Woodbridge Formation was examined within four miles of the glacial conglomerate at Woodbridge, which in other areas denotes the boundary of the Woodbridge and the Grange Mudstone. Two large areas of Woodbridge Glacial Formation were mapped, the more northerly extending south from Allens Rivulet, and the other covering most of the country between Oyster Cove and Snug.

In a small quarry at 509140 E-706120N, south of Allens Rivulet, the formation has the appearance of a well jointed, massively bedded sandstone which is yellow in colour. Further south the rock is much finer grained and very similar to the Grange Mudstone both in appearance and in fossil content although the fossils are not as abundant. On the south edge of the same outcrop, slightly higher stratigraphically, the rock is more sandy, with *Spirifer* and related genera replacing *Fenestella* and *Stenopora*. Ascending the hill towards 506910 E-701710 N, the rock changes from a sandy mudstone containing occasional Spirifer at the creek, to a dense grey very fine grained unfossiliferous mudstone containing occasional boulders, some of which are over 30 cm. in diameter. On the hill-top, immediately south of this point, a band of conglomeratic material may represent the Risdon Sandstone but this could not be confirmed. If this is the Risdon Sandstone, the upper 300 feet of the formation is visible from Allens Rivulet to the south.

The lowest part of the southern exposure is notable for the similarity to the Grange Mudstone together with very marked lithological changes in the sediment over a short lateral distance. The greatest change is in grain size. The rock varies from a fine even-grained mudstone with average grain size less than 0·1 mm. and showing distinct bedding, to a coarse sandstone with variable grain size and containing many boulders and pebbles. The erratics are mostly of quartzite though a piece of Owen Conglomerate 20 cm. in diameter and a piece of schist over 30 cm. were found. Higher in the sequence near the Post Office at Oyster Cove, the rock is a dense sandy mudstone, creamy-grey in colour, which has a pink tinge when weathered. Fossils are not common although clayey lenses contain some well preserved specimens. Above this there is a distinct sandy horizon which was traced from Oyster Cove to a point west of Margate, in the south only a few feet thick, but to the north extending 100 feet. This very sandy mudstone is composed of quartz grains of similar size in a clayey matrix and is very friable; fossils are absent.

The upper 50-150 feet of the Woodbridge Formation, is a fine even-grained dense mudstone, which is grey to cream in colour, with poorly defined bedding which breaks with an even fracture leaving a pitted surface. No fossils are present and the rock is composed of quartz grains not greater than 0·5 mm., with the average size very much smaller. The pebbles are few and very small and consist of quartzite or quartz. There are layers only a few inches thick in this upper band which at a glance appears to be a clay pellet conglomerate, but the effect is caused by circular brown markings in the grey mudstone and is probably due to weathering (though found in relatively fresh rock). The thickness of the section of the Woodbridge Glacial Formation measured at Oyster Cove is 470 feet.

General features of the material making up the Woodbridge Glacial Formation are random sorting in a rock made up of extremes in grain size, the grains being mostly tabular in shape with the degree of rounding decreasing as the grain size decreases.

The heavy mineral suite is made up of limonite, ilmenite, rutile, topaz, cassiterite, muscovite, tourmaline and apatite. Two of the grains of ilmenite were completely altered to leucoxene and all others showed some white streaks of this material. Topaz was found in both separated samples of the Woodbridge rock, but in no other Permian formation.

The fossils are similar to those in the Grange Mudstone, but *Terrakea fragile* and *Martiniopsis sp.* of the Grange are replaced by *Polypora sp., Spirifer vespertilio, Mourlonia sp., Warthia sp.* and some ostracods in the Woodbridge Glacial Formation.

Ferntree Mudstone

This upper formation of the Permian System is far less variable than the two previously described, and may be split into three facies which remain constant over the area under discussion. Ferntree Mudstone outcrops at two places on the northern boundary near Lower Longley, underlies the Knocklofty Sandstone on the western edge of the Snug Plain, and occurs again in the south-west near Nicholls Rivulet. The only structures visible are massive bedding and in rare cases, finely laminated bedding is present. This mudstone is unfossiliferous.

At the base of the Ferntree Mudstone there is a band of coarse sediment, the Risdon Sandstone. This occurs in three places near Oyster Cove between the Ferntree Mudstone and the Woodbridge Glacial Formation. In the three exposures the sandstone was identical to similar outcrops on the lower slopes of Mount Wellington. At least 90 per cent of the material is well-rounded quartz with an average grain size of between 0·12 and 0·06 mm. The remainder of the rock is feldspar most of which has been altered to sericite. The heavy mineral suite was much more limited than in the other Permian rocks, haematite and garnet being quite common while zircon and tourmaline formed only a very small proportion.

The lowest facies of the Ferntree Mudstone is well exposed directly above the Risdon Sandstone at Oyster Cove. The mudstone is grey with an irregular fracture and is composed of a very fine crystalline matrix which comprises 60 per cent of the rock. The remainder consists of quartz grains which may be as large as 1 mm. When weathered the appearance of the rock changes very little but tends to become rather glazed in places. Cliffs of this lower section are very common in the Oyster Cove area, the best examples being the two scarps at Snug Falls. As local fracturing is not present weathering is responsible for this type of exposure. All cliff faces of the lower Ferntree Mudstone are covered with a white incrustation of epsomite which may be up to half an inch thick.

Above the grey mudstone there is a horizon of yellow sandy mudstone which, though similar in grain size to the lower facies, has a very small percentage of the crystalline matrix. Thus the rock is more friable, and weathers readily to gentle slopes which contrast well with the steep slopes of the upper Ferntree and the cliffs below. The best exposure was found on the Hansen's Mill Road when ascending to the Snug Plain where the measured thickness was 200 feet.

The upper horizon is best exposed above and north of the Huon Road near Lower Longley. The thickness measured to the base of the Triassic is 150 feet. The sediment is practically identical with the lower band except for a marked mottled effect visible in all the exposures. It weathers to a creamy-yellow colour except in wet places where the grey colour remains and the mottling disappears. The upper and lower bands of the Ferntree Mudstone have an average grain size of 0·07 mm., with the average size of the large grains 0·1 mm. Grains are usually discoidal or spherical and sub-angular. The crystal surfaces are predominantly bright and there is a lack of sorting which in this even-textured mudstone indicates a short distance of transport during sedimentation. A little biotite and chlorite occurs as small blades and magnetite is visible in nearly all exposures of the upper facies.

The heavy mineral suite is made up of limonite, ilmenite, magnetite, zircon, apatite and pyrite which all exhibited a greater degree of rounding than the bulk of the sediment, probably due to redeposition of the heavy minerals. Near the igneous contacts the degree of alteration is very much less than in either the Grange Mudstone or the Woodbridge Glacial Formation, some silification which extends 2-4 feet from the contact being the only noticeable change.

The Cygnet Coal Measures which exist further south were not present in the area, and though a traverse was made around the boundary of the Permian and Triassic Systems not even traces of carbonaceous shale could be found. The thickness of the Ferntree Mudstone at Oyster Cove is 650 feet and the measurement varied only 10 feet in three sections.

TRIASSIC SYSTEM

The disconformity reported from other areas between the Permian and Triassic Systems could not be found since the boundary occurs always on steep slopes with deep soil cover. The two formations, Knocklofty Sandstone and Shale, and Feldspathic Sandstone, are both well exposed though the upper formation is found only at Kaoota. The massive form and marked structures of the sandstones suggest rapid accumulation of sediments in a still body of water, while the presence of coal and plant fossils in the upper formation indicates lacustrine conditions.

Knocklofty Sandstone and Shale

The basal grits of this formation as found in other areas are represented only in the north-west corner of the Sandfly Area, where a band of conglomerate three feet thick occurs approximately 10 feet above the base of the sandstone. Quartz pebbles up to 15 cm., together with smaller pebbles of quartzite, were cemented in a matrix of fine quartz grains. The only other exposure showing any resemblance to the above exists at Oyster Cove as a single band of similar sized quartz pebbles, 4 cm. in diameter, 20 feet above the base of the sandstone. In this band all the long axes of the pebbles are horizontal.

The lowest 200 to 300 feet of the sandstone is massive with cross-bedding and slump structures very common. The sediment is even-grained, and brown to cream in colour with some sparkling quartz faces. No grains are larger than 0·5 mm. and few are smaller than 0·1 mm., with the average diameter 0·25 mm. The grains are all rounded with some pitting or etching. Secondary regrowth of quartz in optical continuity with the original grain and secondary interstitial quartz are both usual features. Shale bands in this basal member are indicated by fragments in soil but could not be

examined. Only one band of clay pellet conglomerate was found in a road cutting north-east of Pelverata. The pebbles in this one foot band are all elliptical, flattened to some extent and up to 6 cm. long. In no one section were the lower and upper boundaries of this basal member found.

The Knocklofty Sandstone and Shale, well exposed between Pelverata and Kaoota, changes from a formation predominantly of sandstone at the base to one composed mostly of shale. As the amount of shale increases in the formation so the percentage of feldspar increases. The sandstone is similar to that found in the lower member but contains more feldspar. The soft, friable shale, is finely laminated and composed of quartz grains with minor amounts of feldspar. Mica is present in the bedding planes and is more common in some bands than in others. The colour of the shale bands is either brown, yellow, green, grey or purple. During weathering all the material but quartz is removed, leaving a particularly clean sand which is more noticeable in the sandstone, but is formed also from the shale. The thickness of this upper member of sandstone and shale is approximately 200 feet though the top at Kaoota is hidden by dolerite talus.

The thickness of the Knocklofty Sandstone and Shale measured in the section from Pelverata to Kaoota is 565 feet but this is not precise because of the hidden top of the formation. Fossils were not found even in the shale bands.

Feldspathic Sandstone

Exposed near Kaoota this formation is made up of narrow bands of shale between bands of massive sandstone. The shale bands, estimated to make up 30 per cent of the formation, persist to within 100 feet of the top of the Feldspathic Sandstone. All the outcrops of the formation are very weathered.

The sandstone, buff to brown, is composed mainly of feldspar and quartz. The feldspar forms 70 per cent of the rock and is nearly all altered to sericite; of the remainder the largest proportion is plagioclase. The grains, which vary from rounded to sub-angular, are between 0·5 mm. and 0·1 mm. and average 0·25 mm., which is identical with the grain size of the Knocklofty Sandstone. The shale bands are slate-grey in colour, and except where they are associated with coal are no more than two feet thick. They contain many plant impressions, which are mainly *Phoenicopsis elongatus* and *Cladophlebis australis*. The shale was so soft that it was impossible to obtain sufficiently good specimens for fossil identification.

The coal bands in the vicinity of Kaoota have been tested by several adits and were worked extensively for a short time. The coal occurs in eight bands which alter from several feet to a few inches thick, and usually vary extensively in thickness from place to place. The coals are all black, have a vitreous to bright lustre and an uneven fracture. The type of coal varies from anthracitic to humic and much of the anthracite has been formed by heat and pressure due to dolerite intrusions. The faulting and alteration due to the dolerite have made this coal deposit uneconomical to work and it has never been anything but a minor field. (McIntosh Reid, 1922; pp. 123-146.)

Mica is present only in the lower bands of shale of the Feldspathic Sandstone. The mica then may be used as a marker within the Triassic System. The lowest 200 feet of the system are mica free. The proportion of mica then increases to a maximum just below the top of the Knocklofty Sandstone and Shale and then decreases more rapidly to 150 feet above the base of the Feldspathic Sandstone above which it does not occur.

The thickness of the Feldspathic Sandstone Formation is 690 feet at Kaoota making the total thickness of the Triassic System 1255 feet.

QUATERNARY SYSTEM

Alluvium

The two small areas covered by alluvium are the only evidence of any sedimentation having taken place since the Jurassic Period. Tertiary deposits may have been laid down, but the rapid erosion in steep valleys which is taking place to-day would very soon remove such soft sediments. The alluvium is composed of loose soil shed from the neighbouring hills and dropped in two flat areas where streams flow over adjacent sediment and dolerite. The latter, being removed at a much slower rate has dammed the outlets to the small basins.

IGNEOUS ROCKS

Dolerite

The structure and topography of the area have been controlled by sills and dykes of dolerite. Dolerite is the most common rock type in the area and by far the most constant in appearance and composition. The rock is fine-grained near the contacts and changes to medium-grained from a few feet to 50 feet from the margin. The rock is made up of a ground mass of feldspar laths in which there are occasional grains of quartz. The feldspar is usually labradorite. The augite phenocrysts are large, some showing good twinning.

It is not possible to determine the maximum thickness of the sills. The sill beneath the Grange Mudstone near Sandfly must be at least 1500 feet thick and the sill at Herring Back is in excess of 2000 feet. The Grange Mudstone and Woodbridge Glacial formation have been most affected because the finer bedding allowed easy access of molten rock.

Possibly the most unusual dolerite formation is that which extends up the eastern margin of the Oyster Cove Area as a dyke, but to the north spreads out into a typical sill. Near Snug the margins of this mass form steep angles of 70-80° with the adjacent sediments. Red Hill, near the centre of this dolerite, is composed of a differential mass within the main body. This is a coarse granophyre, consisting chiefly of a granophyric intergrowth of quartz and orthoclase, with a little plagioclase, pyroxene and iron oxide. Throughout the dolerite, graphic intergrowth is not uncommon but nowhere else were such large crystals seen.

The Snug Plain is formed almost completely of dolerite and over this area the texture of the rock is remarkably constant. The eastern scarp of the Plain is never on the contact but always in the sediment, usually from 20-100 feet from the margin and this applies to nearly all the contacts in the area. In a few places the weathering is more pronounced on the dolerite side of the contact.

The dolerite has intruded near or at the base of the Grange Mudstone, towards the top of the Woodbridge Glacial Formation, near or at the top of the Ferntree Mudstone, low in the Knocklofty Sandstone and Shale, into the shale and coal bands in the Feldspathic Sandstone and higher in this formation. The foregoing evidence places the intrusion of the dolerite as post-Permo-Triassic sedimentation. In other areas Tertiary faulting has disrupted the dolerite, and it has therefore been suggested that the dolerite intrusions took place during the Jurassic. No evidence against this was found.

Basalt

Two distinctly different exposures of basalt were found. That near Kaoota has a distinct boundary between it and the adjacent dolerite. The rock is composed of minute feldspar laths, large phenocrysts of augite and smaller phenocrysts of olivine, and is without quartz. The olivine is altering at the edges to serpentine and the feldspar laths show definite orientation round the phenocrysts. Therefore it differs from the dolerites in the lack of quartz, the greater percentage of olivine and the orientation of the feldspar laths. The possibility of its being a chilled margin of dolerite was rejected because it is most unlikely that the dolerite would occur in this form at one place in the area and not at others equally favourable.

At 509400 E-706100 N, pieces of basalt and light-grey vesicular basalt occur with several large blocks of tuffaceous breccia. In the vesicular basalt the vesicles vary in shape and are up to 2 cm. in diameter. The breccia is mainly of tuff with pebbles of basalt and dolerite. Also noticeable are three distinct terraces, almost parallel, with eight feet between the upper two and 13 feet between the lower pair. The terraces and volcanic material are the remaining evidence of at least three basalt flows from some higher source.

There is no evidence for the age of the basalts except that the land has changed little since the extrusions so they have been associated with the other Tertiary basalts of Tasmania.

Syenite

Three dykes of a striking porphyritic rock outcrop at Oyster Cove, intrusive into the dolerite and Permian sediments. These dykes are part of the intrusive complex found to the south-west at Cygnet. The rock is composed of a fine groundmass of feldspar crystals with phenocrysts of augite, hornblende and orthoclase. The orthoclase phenocrysts are the most prominent feature of the rock. They reach 5 cm. in length and frequently contain inclusions of plagioclase. The orthoclase phenocrysts showed a marked change in size, being very large in the centres of the dykes and barely visible at the margins. When exposed to weathering the feldspar phenocrysts soon become loose and dislodged, leaving the dyke with a pitted appearance and a halo of phenocrysts round the margin, for though the phenocrysts become detached easily they do not weather quickly. Foreign boulders of quartz up to 15 cm. diameter and one piece of mica schist, were found in the southern dyke. The sediments show only slight baking at the contacts. Jointing parallel to the strike of the dyke is prominent with minor joints at right angles to the cooling fractures. The age of the syenite is not known, beyond the fact that it intrudes post-upper Triassic dolerite.

STRUCTURAL GEOLOGY

The only structural features of any importance were caused by the injection of dolerite with accompanying faulting after the Triassic sedimentation. These intrusions occurred with no apparent structural control except that where concomitant faulting occurred along the intrusive boundaries there is a general north-south trend. This structure has left an area predominantly of dolerite in which are floating variously sized blocks of sediment. Of the sedimentary exposures it seems probable that only the Knocklofty Sandstone at Longley may be in continuity with the underlying basal sediments.

In the eastern half of the Sandfly Area dolerite has formed two distinct sills, one below the Grange Mudstone, which may be seen in three places, and one above the Woodbridge Glacial Formation. The Grange Mudstone in the north-east corner of the Sandfly Area has been raised by the dolerite, and the concordant boundary of this sill was traced round the contour of the hill. A similar exposure occurs between Sandfly and Allens Rivulet and again the contact was traceable for part of its length, although only in the south-west corner of this outcrop was the junction of the two rock types visible. West of Margate a further occurrence was mapped and once more the contact of the two rock types could be seen. It is not possible to state whether or not these three masses were raised to the same height because of the change in the dip of the three outcrops and the lack of constancy of dip throughout the area. For the same reasons the two northern areas of Grange Mudstone may or may not have been lifted as one block.

Between the southernmost two of these three exposures is a sill of dolerite above the Woodbridge Glacial Formation. The contact of rock types at this boundary was not so easily seen because of the dolerite scree which spreads down the hill. No estimation can be made of the relative movement of these three blocks of sediment because up to the present it is not possible to tell at what horizons in the sediments the dolerite has been injected. Also, no section in the area permitted the measurement of these formations.

In the Nicholls Rivulet basin the faulting is complex. The step faulting of the contact between the Knocklofty Sandstone and dolerite and between the Knocklofty Sandstone and Ferntree Mudstone is readily detected in the steep cliffs surrounding the basin. There is evidence that the main north-south fault through the basin is of pre-Tertiary age, and was connected with the intrusion of dolerite: Nicholls Rivulet does not follow the fault quite as clearly as it would if the fault were recent, no signs of a fracture zone were found, and baked sediments occur against the fault on its eastern side near the Oyster Cove Road. It is probable that the dolerite on the west of the basin was intruded first, beneath the Ferntree Mudstone and the Woodbridge Glacial Formation. A second intrusion then caused the minor faulting to the east. The three oblong outcrops of dolerite shown between the Knocklofty Sandstone and the Ferntree Mudstone, together with baked sediments on one of the faults well removed from the nearest dolerite exposure, are indicative of a second sill below the sediments east of the main fault. Though the strike and dip of the sediments in all the fault blocks were not obtainable, enough were measured to show much greater change of inclination of the sediments across faults of greater vertical displacement.

The main dolerite mass in the area extends as an unbroken exposure from north to south and from east to west in the north. This mass is bounded in the south by a series of concomitant faults. Some faulting extends also to the north but parts of the same mass have spread as sills over the Feldspathic Sandstone and below both Grange and Woodbridge sediments. Along all the contacts sediments are baked and invariably the intrusive body is fine grained near the margin. Near Sandfly one undetermined block of sediments has been completely changed to hornfels. The grain size of the intrusive mass away from the margin is remarkably constant.

Near Kaoota there are small lenses of the above dolerite intruding the sediments, some extensive in both thickness and area and at least one only inches thick in one of the old adits above the Kaoota-Pelverata Road. The same dolerite has been intruded into the Woodbridge Glacial Formation in the form of miniature inch-wide dykes, as though the dolerite has been forced into existing joints in the sediments. Tertiary faulting, prominent to the east and west of the area, was not found here.

Jointing in the dolerite is universal and the three directions are constant, 80°, 135° and 170°. In most exposures only two of the three directions occur but the three are occasionally developed. The joint direction of 170° is the most common and 135° joints are rare. A very good example of columnar jointing occurs at Sandfly Falls and there are minor exposures at Allens Rivulet and Kaoota.

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LOCALITY INDEX

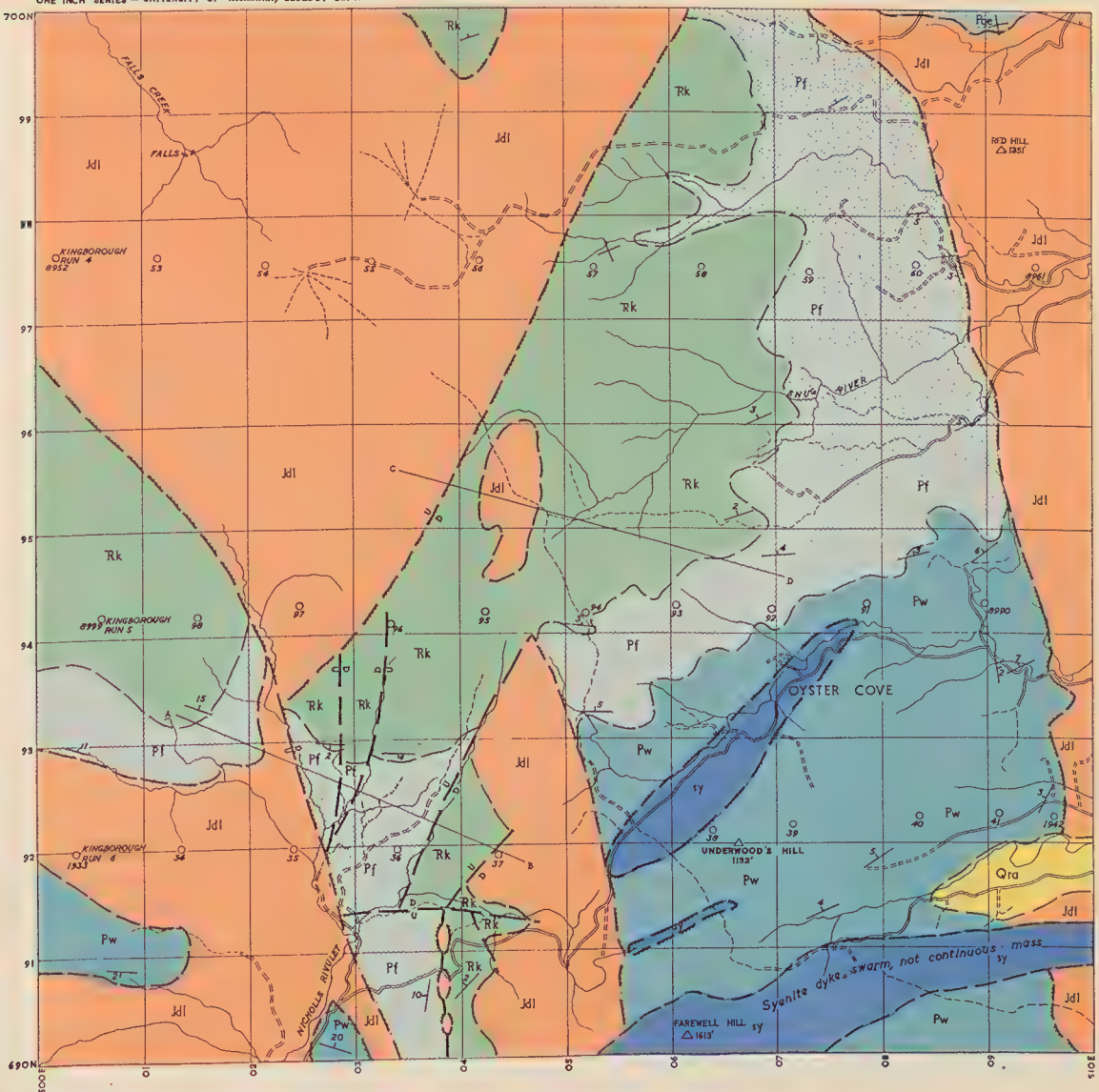
	Internat. Grid Reference K/55 Quadrangle	S. Lat.	E. Long.
Allens Rivulet	Kingborough 88	43° 1′	147° 10′
Cygnet	Kingborough 88	43° 10′	147° 7′
Herring Back	Hobart 82	43° 0′	147° 9′
Kaoota	Kingborough 88	43° 1′	147° 10′
Longley	Hobart 82	42° 58′	147° 12′
Lower Longley	Hobart 82	42° 59′	147° 8′
Margate	Kingborough 88	43° 2′	147° 16′
Mount Wellington	Hobart 82	43° 6′	147° 14′
Nicholls Rivulet	Kingborough 88	43° 10′	147° 7′
Oyster Cove	Kingborough 88	43° 6′	147° 12′
Pelverata	Kingborough 88	43° 3′	147° 7′
Red Hill	Kingborough 88	43° 4′	147° 13′
Sandfly	Hobart 82	43° 3′	147° 7′
Snug	Kingborough 88	43° 4′	147° 15′
Snug Plain	Kingborough 88	43° 5′	147° 10′
Woodbridge	Kingborough 88	43° 10′	147° 14′

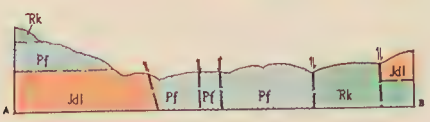
GEOLOGY OF TASMANIA

ONE INCH SERIES — UNIVERSITY OF TASMANIA, GEOLOGY DEPT.

OYSTER COVE

5069





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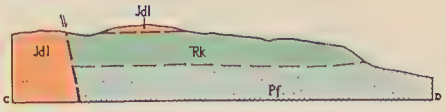

LEGEND

- FAULT WITH DOWNTHROWN SIDE INDICATED
- FAULT — POSITION APPROX.
- FORMATION BOUNDARY — POSITION APPROX

Dolerite Boundaries

- CONCORDANT SILL
- DISCORDANT INTRUSIVE BOUNDARY

- STRIKE AND DIP
- HORIZONTAL BEDS
- ROADS
- VEHICULAR TRACK
- TRACK
- TRIGONOMETRICAL STATION
- PHOTO CENTRE
- TRANSMISSION LINE

Quaternary System

RECENT SERIES

- Qra ALLUVIUM

Triassic System

- Rf FELDSPATHIC SANDSTONE
- Rk KNOCKLOFTY SANDSTONE AND SHALE

Permian System

- Pf PERRTREE MUDSTONE
- Pw WOODBRIDGE GLACIAL FORMATION
- Pge GRANGE MUDSTONE

IGNEOUS ROCKS

- sy SYENITE PORPHYRY

Jurassic (?) System

- Jdl DOLERITE

Compilation from Aerial Photographs.
Trigonometric Station Control by courtesy Lands and Surveys Department.
Origin of coordinates 400,000 yds. West and 1,800,000 yds. South of True Origin of Zone 7 of the International Grid.

KEY MAP SHOWING MAGNETIC DECLINATIONS SECULAR VARIATION 7 MINS. R.A.

MAPPED AND COMPILED BY
T.H. RODGER 1952

SCALE

0 1 2 3 4 5000 — 2 MILES — 10000 FEET

GEOLOGY OF OYSTER COVE AREA.

SHEET 5069

PHYSIOGRAPHY.

This area has a relief of somewhat less than 2,000 feet with an early mature topography. The most prominent feature is Snug Plains, drained to the south by Nicholls Rivulet and to the east by the Snug River and other streams. The streams are all in mountain tract with falls and rapids a common feature. Snug Falls and falls on Falls Creek are the most spectacular. There is an overall control of stream courses by local structure or rock type, e.g. Nicholls Rivulet is partially fault controlled, but superimposition of streams is suggested by the transgressive relationship of the stream course to the structure.

STRATIGRAPHY.

The oldest formation is the Grange Mudstone which occurs in the north-eastern part of the area. This formation consists of creamy siliceous banded mudstone which is richly fossiliferous, the main fossils being fenestellids and **Strophalosia** spp. The next formation is the Woodbridge Glacial Formation of sandstones and siltstones with erratics and fossils such as **Spirifer vespertilio** and **Warthia.** It is 470 feet thick at Oyster Cove. Near Oyster Cove the Woodbridge Formation is overlain by Risdon Sandstone and this by the Ferntree Mudstone which is about 650 feet thick. This last formation consists of grey mudstone and yellow sandy mudstone. No trace of the overlying Cygnet Coal Measures was seen.

Of the Triassic System only the Knocklofty Formation occurs. A pebbly conglomerate occurs about 20 feet above the base to the north west of Oyster Cove. The formation is dominantly quartz sandstone with some quartz siltstone.

The Permian and Triassic sediments are intruded by sills and dykes of dolerite many of the contacts in this area being very steep. The dolerite and the Permian sediments up to the Woodbridge Formation are intruded by dykes of syenite porphyry which trend somewhat east of north. The age of the syenite is not known.

Small areas of alluvium occupy some of the river valley.

PETROLOGY.

Of particular interest is the occurrence of a mass of coarse granophyric dolerite at Red Hill, which contains quartz, orthoclase, plagioclase, pyroxene and iron oxide in granophyric intergrowth. The syenite porphyry has been described by Edwards. The most prominent feature is the occurrence of large sanidine phenocrysts.

STRUCTURAL GEOLOGY.

The main structural features are the faults associated with the dolerite intrusions. In the eastern part of the area part of a horst is occupied by dolerite with a steep contact against the Ferntree Mudstone downthrow to the west. The fault initially trends south-east but swings progressively to the south. Further west the main mass of dolerite forming Snug Plains is downfaulted by a north-easterly trending fault against Triassic sediments. The Snug Plains block is cut off to the south-west by a south easterly trending fault which downthrows to the north-east so that the Snug Plains block is part of a graben. Another smaller graben occupies the central southern part of the area.

ECONOMIC GEOLOGY.

Very small amounts of gold are found in the stream flowing just north of Oyster Cove. This is presumably associated with quartz veins associated with the syenite porphyry.

POINTS OF SPECIAL INTEREST.

Granophyric dolerite: Red Hill (509.2E.698.7N)

Snug Falls (507.4E.698.4N)

Syenite porphyry (Oyster Cove Road, Oyster Cove)

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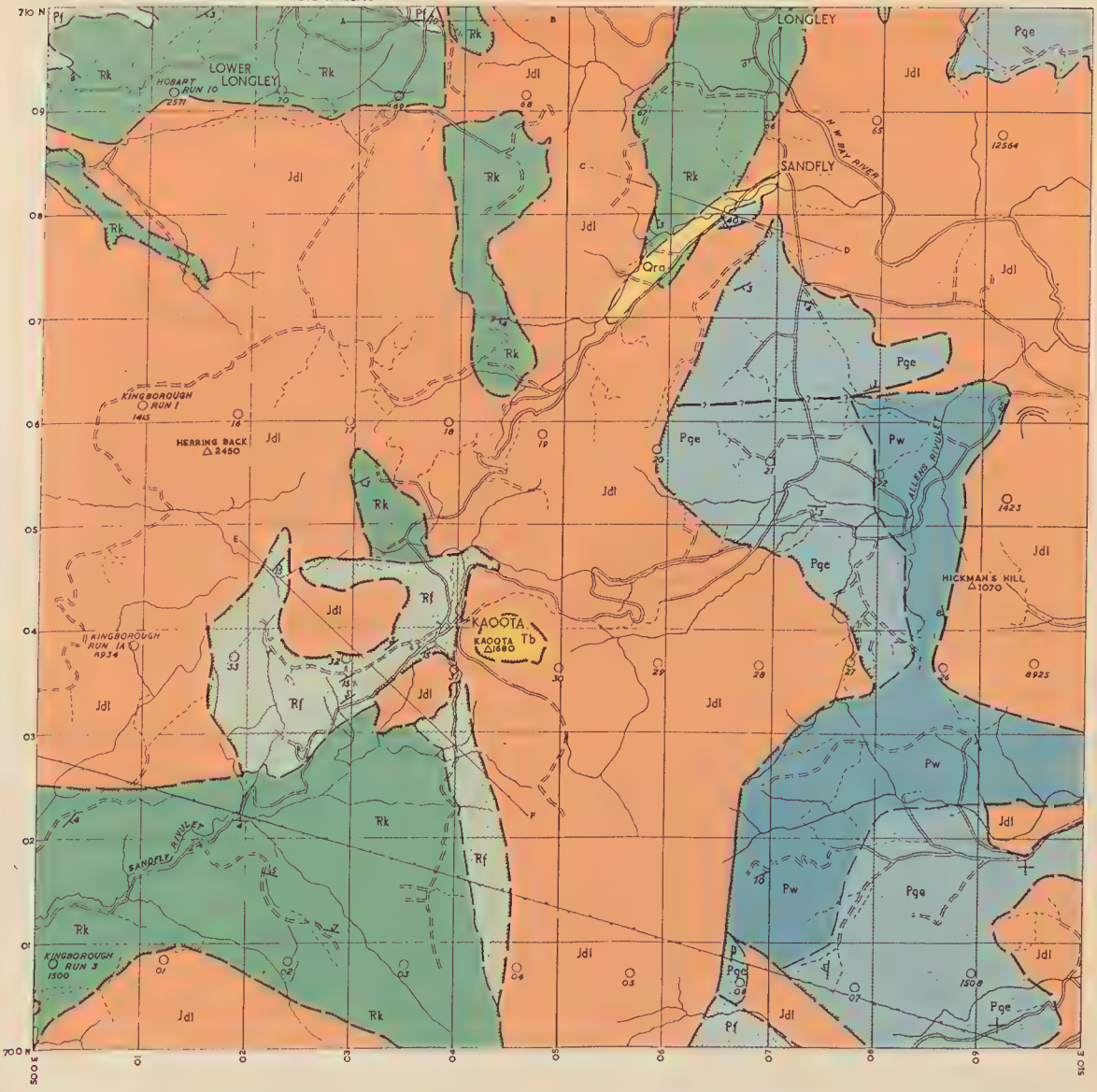
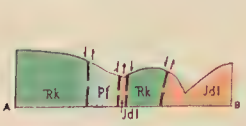
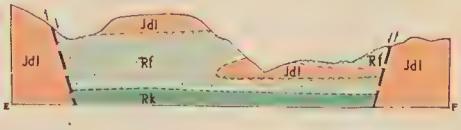
SANDFLY







LEGEND

- FORMATION BOUNDARY
- FORMATION BOUNDARY – POSITION APPROX.
- FORMATION BOUNDARY – INFERRED
- FAULT – INFERRED

Dolerite Boundaries

- CONCORDANT SILL
- DISCORDANT INTRUSIVE BOUNDARY

- STRIKE AND DIP
- HORIZONTAL DIP
- ROAD
- VEHICULAR TRACK
- TRACK
- TRIGONOMETRICAL STATION
- PHOTO CENTRE
- TRANSMISSION LINE
- ADIT

Quaternary System
RECENT SERIES

- Qra ALLUVIUM

Triassic System

- Rf FELDSPATHIC SANDSTONE
- Rk KNOCKLOFTY SANDSTONE AND SHALE

Permian System

- Pf FERNTREE MUDSTONE
- Pw WOODBRIDGE GLACIAL FORMATION
- Pge GRANGE MUDSTONE

IGNEOUS ROCKS
Tertiary System

- Tb PLIOCENE(?) BASALT

Jurassic(?) System

- Jdl DOLERITE

Compilation from Aerial Photographs. Trigonometric Station Control by courtesy Lands and Survey Department. Origin of coordinates 400,000 yds. West and 1,800,000 yds. South of True Origin of Zone 7 of the International Grid

MAPPED AND COMPILED BY

T.H.RODGER 1952

KEY MAP SHOWING MAGNETIC DECLINATIONS
SECULAR VARIATION 7 MINS. P.A.

– SCALE –

0 2 MILES

0 1 2 3 4 5,000 10,000 FEET

THE GEOLOGY OF SANDFLY.

SHEET 5070

PHYSIOGRAPHY.

This is an area of youthful or early mature topography dominated by the high dolerite ridge of the Herring Back which reaches 2,450 feet above sea level. The area is drained by the Sandfly Rivulet, Allens Rivulet and North West Bay River. These are in their mountain tracts and only locally are there flats at or about present stream level. Generally the streams flow through Permian and Triassic sediments leaving the dolerite as the higher land but the North West Bay River has cut most of its course through dolerite. It may be a superimposed stream. There is a somewhat radial drainage of the Herring Back.

STRATIGRAPHY.

The oldest rock is the Grange Mudstone (Permian) which is a banded siliceous mudstone, usually creamy yellow in colour, and with abundant fossils e.g. **Fenestella, Stenopora,** and **Strophalosia.** It is commonly contact metamorphosed over considerable areas by dolerite intrusions. The Grange Mudstone is followed by the Woodbridge Glacial Formation which is a formation of yellowish thickly bedded sandstone and thinly bedded mudstone with erratics up to a foot in diameter. Fossils are present and include **Terrakea fragile, Spirifer vespertilio** and **Warthia.** The formation is 470 feet thick. The Risdon Sandstone does not occur in this area. The Ferntree Mudstone occurs in several isolated patches. It is a formation of thickly bedded, non-fissile siltstone and thinly-bedded fissile siltstone with some sandy bands and rare marine Permian fossils. In an adjacent area it is 650 feet thick.

The lower formation of the Triassic System is the Knocklofty Sandstone and Shale. A conglomerate 3 feet thick occurs 10 feet above the base near Lower Longley. Both sandstone and shale are very siliceous. Cross-bedding and slump structures are common in the lower part of the formation near Longley and Lower Longley. The lower part is thickly bedded. The formation is 565 feet thick near Kaoota. It is followed by the Feldspathic Sandstone which is a very feldspathic (even arkosic) sandstone with associated grey shales which contain **Phoenicopsis elongatus** and **Cladophlebis australis** and many other plant fossils. At least eight beds of coal are present in this formation which has a thickness at Kaoota of at least 690 feet.

The sedimentary rocks have been intruded by sills and dykes of dolerite (probably Jurassic in age). The sill below the Grange Mudstone near Sandfly is at least 1,500 feet thick. The sills are irregular and somewhat transgressive.

Olivine basalt covers a small area near Kaoota and is correlated on petrographic grounds with the Tertiary basalts in other areas in Tasmania.

A small area of alluvium occupies part of a stream valley near Sandfly.

STRUCTURAL GEOLOGY.

Dips in the sediments are all low. The main structural feature is the faulting associated with the intrusion of the dolerite. The effect of this faulting has been to downthrow the western and north western part of the area along a dyke trending south-east from Sandfly and turning south at Kaoota. On the western side of this dyke minor faults trend mainly north or east. Faults with easterly trend also occur east of the dyke and in the southern part of the area two step faults trending north-west form a small horst.

ECONOMIC GEOLOGY.

The main point of economic interest is the coal. It is Triassic in age. There are eight seams of anthracitic to humic coal, the anthracite being produced by dolerite intrusion. Eight adits have been opened some of which are still being worked.

Sand for building purposes is quarried between Sandfly and Longley. It is produced by weathering of the Knocklofty Formation **in situ.**

POINTS OF SPECIAL INTEREST.

Longley-Sandfly Road: sedimentary structures in Triassic sandstone.

Kaoota: basalt.

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PROVENANCE OF CERTAIN TASMANIAN ORDOVICIAN CORALS

By

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Curator of Fossils, National Museum of Victoria

(Communicated by Professor S. Warren Carey)

ABSTRACT

Registered numbers and further information of the localities from which they came are provided for Ordovician corals from Tasmania, described by Dr. Dorothy Hill.

In Volume 89 of these Proceedings, Dr. Dorothy Hill (1955) described a series of fossil corals from Tasmania. Among them were some Ordovician corals referred to as being in the collections of the National Museum of Victoria, Melbourne. The purpose of this note is to provide Museum numbers for these specimens, and to increase the stratigraphic value of the determinations by giving further details of the provenance of the specimens.

The fossils in question were collected by the writer when on a geological excursion to Western Tasmania in December, 1947, under the guidance of Professor S. Warren Carey and Mr. M. R. Banks. The writer was not then on the staff of the National Museum, and so the specimens had labels only and no Museum numbers. At some time during the interval, some of the labels were lost, so Dr. Hill recorded fossils as being from Bubb's Hill, or Queenstown, or Zeehan. Reference to correspondence shows that I forwarded to Dr. Hill fossils only from Bubb's Hill and Zeehan, so the third possibility can be ruled out. The two localities can be defined as follows:—

1. Near Hydro-Electric Commission transmission line tower 287, south of the Lyell Highway, and on the north-west flank of Bubb's Hill, Victoria Pass, Western Tasmania. Bubb's Hill is shown on the "State Map 4 M" of Tasmania published by the Surveyor General's Office, Hobart, Tasmania.
2. Smelters' limestone quarry, about one and a half miles south of Zeehan, and west of the Smelters' Works (see Gill and Banks, 1950, map, plate 2). Subsequently in this note, the fossil localities listed here are referred to simply as localities 1 and 2. The two localities are regarded as outcrops of the same formation (Loftus-Hills and Carey, 1949).

The following list comprises the registered numbers in the National Museum of Victoria, the specimens to which they refer, and the localities from which they came. The registered numbers have reference to the physical entities only, and not to the biological specimens they comprise or contain (Gill, 1953, p. 157).

P 16738 *Propora* cf. *hirsuta* Lindström. Loc. 1 or 2. Hypotype in part, viz., part of piece of rock from which were cut the slides figured in Pl. 2, figs. 22 A, B. A type specimen is a biological and not a lithological one. It is an individual or single colony of animal or plant selected from a population as typical, and thus becomes a fixed point in taxonomy. In the present instance, a colony of *Propora* is made a hypotype. It is fragmented into a number of pieces, but each is part of the hypotype, i.e., of the coral colony concerned.

P 16739 Same. Hypotype in part. Eight fragments of same piece of rock.

P 16740 Same. Hypotype in part (tectohypotype). Slide figured in Pl. 2, fig. 22 A. Transverse section.

P 16741 Same. Hypotype in part (tectohypotype). Slide figured in Pl. 2, fig. 22 B. Vertical section.

P 16742 *Nyctopora* sp. The specimen also contains *Eofletcheria ida* Hill. Loc. 1. Figured specimen in part, viz., the piece of rock from which were cut the slides figured in Pl. 2, figs. 30 A, B.

P 16743 Same. Slide figured in Pl. 2, fig. 30 A. Transverse section.

P 16744 Same. Slide figured in Pl. 2, fig. 30 B. Vertical section.

P 16745 *Plasmoporella* sp. Loc. 1. Figured specimen in part, viz., the piece of rock from which was cut the slide figured in Pl. 2, fig. 31.

P 16746 Same. Slide figured in Pl. 2, fig. 31.

P 16747 *Plasmoporella* sp. Loc. 1. Figured specimen in part, viz., the piece of rock from which was cut the slide figured in Pl. 2, fig. 32. Dr. Hill writes, "The specimens from Bubb's Hill, may well be conspecific with the form described by Hill (1942, p. 10, Pl. 2, figs. 10 *a*, *b*) from the head of the Nelson River". The latter locality is more or less the same as loc. 1, as one branch of the Nelson River rises at Bubb's Hill. Dr. W. R. Browne, who collected the specimen described by Dr.

Hill in 1942, advises me that he obtained it from near the Lyell Highway at Bubb's Hill. Professor S. W. Carey has pointed out that although these outcrops on and near Bubb's Hill belong to the same formation, there is a fault between the hill and the highway, so that specimens from adjacent points may nevertheless be considerably apart stratigraphically. Dr. Browne has drawn attention to the fact that there is another Nelson River in Western Tasmania, just south of the Arthur River and heading near Balfour.

P 16748 Same. Slide figured in Pl. 2, fig. 33.

P 16749 *Eofletcheria ida* Hill. Loc. 1 or 2. Paratype in part, viz., a piece of the specimen from which was cut the slide figured in Pl. 2, fig. 35.

P 16750 Same. Paratype in part, viz., five fragments of the same piece of rock.

P 16751 Same. Paratype in part (tectoparatype), viz., slide figured in Pl. 2, fig. 33.

The writer is indebted to Dr. Dorothy Hill, Professor S. Warren Carey, and Dr. W. R. Browne for checking a draft copy of this note.

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Papers and Proceedings of the Royal Society of Tasmania, Volume 91

THE PRESENT STATUS OF SOME TASMANIAN MAMMALS IN RELATION TO THE FUR INDUSTRY OF TASMANIA

By

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(With 10 Text Figures)

INTRODUCTION

In making a general survey of the status of an economically exploited species, several workers have made use of the returns made by commercial hunters. Examples of this are found in papers by Colman (1937 and 1949), Chitty and Elton (1937) and Chitty (1938, 1939, 1940). Colman evaluated the status of the Newfoundland Seal Industry while the other workers were engaged in the well-known Arctic Wild Life Enquiry. There is also a growing use of kill data as a basis for calculating the density of natural populations. I propose here to give an account of the status of some of the Tasmanian fur and game mammals, and to review the fur industry, using information derived from the fur and game statistics. In this paper I will not make any attempt to estimate total populations of the various species.

The fur industry in Tasmania at present is not very remunerative but it is of some importance in the highland country districts where it provides a supplementary income during the slack winter months.

The statistics of the industry are rather poor. I have not been able to obtain the details of catches prior to 1947. These returns once existed and were used by Pearson (1938), but all records up to and including 1946 were destroyed in 1947 and so details of the various licences issued before 1947 are not available. The authorities do not consider it necessary to preserve these records and they are destroyed from time to time, but some details, although inadequate, are recorded here for future workers.

The prevailing prices for skins are not shown in any statistical surveys issued by either the Commonwealth Bureau of Statistics or the Tasmanian Statistical Office. The total value of the skin industry is given by the former, but this sum includes rabbit as well as marsupial pelts and it is not possible to abstract details of each species. I have not been able to obtain the prices paid to trappers for pelts for the period 1923-1955.

Throughout this paper I intend to follow Troughton (1941), Guiler (1953), and others and use the term "possum" for the Australian phalangers, reserving the word "opossum" for the American Didelphids. The nomenclature used is that of Iredale and Troughton (1934).

THE ANIMALS

The fur industry at present exploits Bennett's Wallaby, *Wallabia rufogrisea* (Desmarest) v. *bennetti*, as one of the principal furbearers of the State. This species, although a wallaby, is known throughout Tasmania as the kangaroo or simply 'roo. The species is plentiful in many parts of the State and has reached pest numbers in north-eastern and north-western Tasmania. In the north-east and east there is a 12 month open season (1952-1955) and in the north-west, special hunting permits have been granted to landholders to kill *Wallabia* throughout the year. Troughton (1941) quoting Gould who wrote in the early colonial days, records that this species was hunted for food and skins, the latter being exported to England for manufacture into boots and shoes. The pelts then fetched 4d.-6d. each.

The smaller Thylogale, *Thylogale billardieri* (Desmarest) or Red-bellied Pademelon is also hunted for its pelt. This species is known locally as the wallaby. Troughton, again quoting Gould, notes that this species also was hunted for its skin in the early days of the colony.

Both of these macropods are extensively hunted for meat and sport. The large forester kangaroo *Macropus tasmaniensis* Le Souef used to be hunted commercially but the species is recorded by Troughton as "hunted to the verge of extinction". It is now a completely protected species and is found in the north-east corner of the State and also at Lake Tooms. The area in the north-east where the kangaroo is found has been declared recently as an area for agricultural development. It is therefore very doubtful if this species will survive in that area.

Pseudocheirus convolutor (Oken).

The Ringtail Possum is found throughout Tasmania with the possible exception of myrtle forest areas. In the past, this species was a major item in the Tasmanian fur industry, but in recent years (1950-55), due to the prohibition of the steel gin trap, these animals, which spend little time on the ground, have proved difficult to trap and are no longer hunted commercially.

Trichosurus vulpecula (Kerr).

This possum, the Brush, is larger than the Ringtail and is hunted commercially, having a more valuable fur. Three types of possum are listed in the skin returns. These are Ringtail, noted above, the Black Possum and the Grey Possum. Black and grey are the principal colour phases of the Brush Possum but are listed separately on account of the difference in value of the black and grey pelts. Pearson (1938), Huxley (1942) and Guiler (1953) have discussed the distribution of the black and grey varieties, in relation to climatic and other factors, the most recent work showing that the black phase is found in areas with high rainfall and humidity combined with suitable vegetation. The species is more omnivorous than the Ringtail and spends more time on the ground seeking food and so is easier to trap than *Pseudocheirus*. These animals can become friendly to humans, and one is well-known at a hiker's hut where it eats anything from lamb chops to sweet cakes.

Hydromys chrysogaster Geoffroy

This rodent, locally known as the water-rat, is highly esteemed for its pelt which is soft, dark on the back but golden-yellow on the belly. The species is generally distributed but is not plentiful in any one area. It inhabits rivers and creeks and has been seen fishing on the seashore. *Hydromys chrysogaster* is not confined to Tasmania but is also found on the mainland of Australia.

Oryctolagus cuniculus (L.)

The rabbit is important to the fur industry of Tasmania and during the War, trappers made much money from the sale of rabbit skins. The rabbit is found over a great area of Tasmania but is absent from rain forest areas and places isolated by these forests. It does not favour certain types of low quality scrub in the south and west of Tasmania.

Dama dama (L.)

The European Fallow Deer, *Dama dama* (L.), was introduced into the midlands district of Tasmania for sporting purposes. While this species is not utilized commercially, it is included in the present survey since it provides a source of revenue to the Government through licence fees.

Other Species

Previous to the introduction of protective regulations, many other species of mammals were killed for their pelts, in particular, the Forester Kangaroo, Tiger Cat and Native Cat. The platypus, *Ornithorhynchus anatinus* (Shaw and Nodder) was also extensively hunted. These species are now, along with all other marsupials and monotremes, wholly protected.

Seals, *Gypsophoca tasmanica* Scott and Lord, were exploited in the early days of the Colony, particularly in the Bass Strait Islands. This industry acquired a reputation not only for cruelty to the seals but also for the ruthlessness with which the hunting was carried out. Nowadays seals may be hunted under licence but very few licences have been issued since the War. Seals are often shot by fishermen, who regard them as a menace to fishing.

CONTROL

The control of the trapping and killing of native animals is vested in the Animals and Birds Protection Board under the Animals and Birds Protection Act 1929. The Board issued new regulations under the Act in 1953 (Tasmanian Government Gazette). The Board consists of representatives of the skin dealers, trappers, scientists and of sporting bodies. The landowners and farmers are also represented and there is a Government nominee.

The Board, often referred to as the Fauna Board, is invested with the power of declaring open seasons, protecting animals and declaring sanctuaries. The issuing of various licences is also a function of the Board.

The Act is enforced by members of the Tasmania Police who are seconded to the Board as Inspectors. At present there are two Inspectors.

Licences are required to hunt wallaby, thylogale or possum and to sell the skins to dealers. Skin dealers require a licence to trade in skins. Dealers' agents also have to be licensed. It is not necessary to obtain a licence to hunt on private land, but it is necessary to have a licence to sell the skins caught there. Restricted licences are issued to enable an individual to purchase skins for private use.

Royalties are payable on all skins taken except those of the rabbit. The royalties can be paid at any police station by the hunter, dealer, or dealers' agent. The pelt is then stamped "Royalty Paid Tasmania" in a circular stamp.

The police officer, in making out the receipt for the royalty, records the number of pelts of each species and the locality whence they were taken. These records were utilized in the surveys of the colour phases of the Brush Possum mentioned above.

The open season for game is usually held during the winter months of June-July. At this time of the year, the pelts are in good condition, although the females of all species are usually carrying young. The pouch young of kangaroos vary considerably in size during these months, which points to a protracted breeding season (Asdell, 1946 and Zuckerman, 1953). The possum young are also in different stages of development, due to two breeding seasons per annum (Asdell, 1946). This makes it difficult to prevent the taking of females whilst they are carrying young.

Methods

(*a*) Wallaby and Thylogale

Under Section 44 of the Regulations all set snares or traps must be inspected at 36-hour intervals and animals removed therefrom. This regulation, necessary from the humanitarian viewpoint, often inflicts some handicap on highland trappers, necessitating trips around a 10-mile trap line in snowstorms and other adverse weather conditions.

Wallabies and thylogales are hunted by a variety of means. Some hunters maintain packs of dogs, which are of a "greyhound throwback" type and are used for running the wallabies to a standstill, when they are shot. Often small dogs called "yafflers", are used to put up the wallabies out

of thick scrub. Both these macropods are largely killed for their skins although some are sold for meat. Snares are used widely in the trapping of wallabies and thylogales for skins, the animals usually being skinned on the spot and the skins stretched at camp, the carcase being left in the bush.

Smoking out game is forbidden, as is the use of spears and chemicals. Lights for night shooting are prohibited.

(*b*) Possums

Section 40 of the 1953 regulations forbids the use of steel gin traps for taking these animals and this restricts the catch to Brush Possums since the Ringtails spend most of their time in trees and are difficult to snare. Shooting of possum is illegal (as is the possession of skins of animals which have been shot, Sections 38 and 39 of the Regulations). Largely on account of the difficulty of snaring Ringtails there has not been an open season for taking this species since 1949. Previously, the species was caught in ordinary rabbit traps.

The Brush Possum spends a proportion of his time on the ground and his home tree can be readily identified by the scratches on the side of the trunk. The animal climbs up the side of the trunk which has the least vertical slope and if a log is placed at an angle from the ground to this trunk, the possum will use it to gain its home. A wire running noose snare is placed on this log. The animal, usually dead, is removed and taken to camp before being skinned (local terminology—skun). Brush Possums have to be cold before skinning otherwise the fur tears out of the skin. The corpses may be fed to dogs, buried, or more often dumped in the bush. The methods of skinning closely follow those used in New Zealand and described by Pracy and Kean (1949).

(*c*) Water-Rat

The water-rat is snared on tracks on the banks of rivers, streams or swamps. The snare employed is a running noose arranged so that least damage will occur to the pelt.

(*d*) The Rabbit

The rabbit does not come under the regulations and any method may be used for killing or trapping the pest. Graziers run a furrow and free feed the rabbits on apples or carrots, then using some mixed with strychnine, poison them. The skins are not used and the corpses are buried or burned. Warrens are ploughed in or gassed, and the myxomatosis virus has been introduced in Tasmania with varying success. The poison "1080" (sodium monofluoro-acetate) has recently been used in place of strychnine and has yielded excellent results.

Trappers are employed by the sheep graziers. They are paid a wage and allowed to sell the skins and meat. They use rabbit traps, dogs, or ferrets and nets. The success of myxomatosis and "1080" poisoning has greatly reduced the number of trappers in Tasmania.

The pelts are detached and sold and the carcases are sold in grocers' and butchers' shops. In recent years, an export market to England has developed, the carcases being exported either frozen or canned.

One of the unfortunate features of the fur industry is that a number of other species which have no value commercially are caught and killed. Snares and rabbit traps account for most of these casualties. The Tasmanian Devil *Sarcophilus harrisii* Boitard is frequently caught, especially in the Great Lake-Bothwell area and the north-east coast.

Native cats, *Dasyurus quoll* (Zimmermann) and tiger cats, *Dasyurops maculatus* (Kerr) are also trapped as well as bandicoots, rat kangaroos and other small marsupials. The smaller marsupials, pigmy possums, marsupial mice and gliders, are only rarely trapped.

THE STATISTICS OF EACH SPECIES

It is not possible to give a detailed treatment of the figures available as several of the important elementary sets of figures are not available. The hunters' licence entitles the holder to take all game, and so it is impossible to calculate the number of persons engaged on any section of the industry. It is possible to abstract accurate figures for the number of water-rat and deer licences issued, but in the latter case there is no return kept of the number killed.

All licence statements prior to 1947 were destroyed by the Police Department so that these records are not available.

Licences for Taking Possums, Wallabies and Thylogales

A licence is required for hunting on Crown land and another licence is necessary to be enabled to sell the pelts so taken. Similarly, a licence is necessary to sell skins taken on private property, but no licence is required to hunt there. The number of licences issued during 1949-55 is shown in Table 1. The years 1947-8 were open seasons only, on King Island and the number of licences issued was low.

An indication of the number of professional hunters working in the industry can be estimated approximately, by counting those licences both for hunting and selling which have been paid simultaneously by one person. These licences have been treated separately in the analysis of licence data and are shown as combined hunters' and sellers' licences in Table I. In 1949 Brush and Ringtail Possum, kangaroo and wallaby were open for hunting and a large number of hunters entered the industry. The years 1950-1 were closed for phalangers and the emphasis of hunting was on kangaroo and wallaby. There were very few professional trappers in the industry in 1955.

In some instances, trappers hunt both possums and kangaroos and others hunt only one species.

(*a*) The Water Rat

Prior to 1942 there are no figures available for the numbers of water rats captured. The figures since 1942 are shown in Table II and are graphed on figure 1.

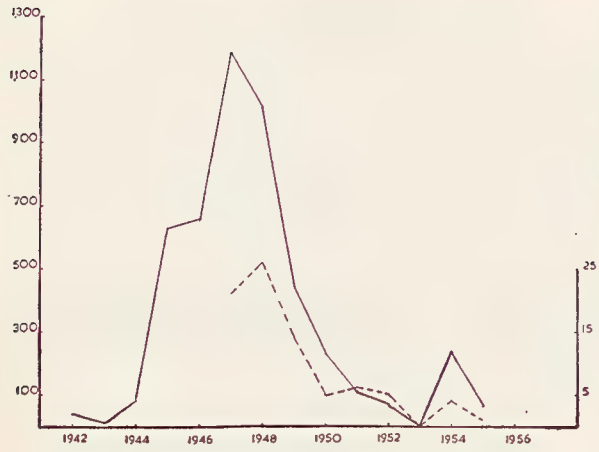

FIG. 1.—Total catch of water-rats for the period 1942 to 1952. The dotted line shows the number of licences issued for the period 1947 to 1951.

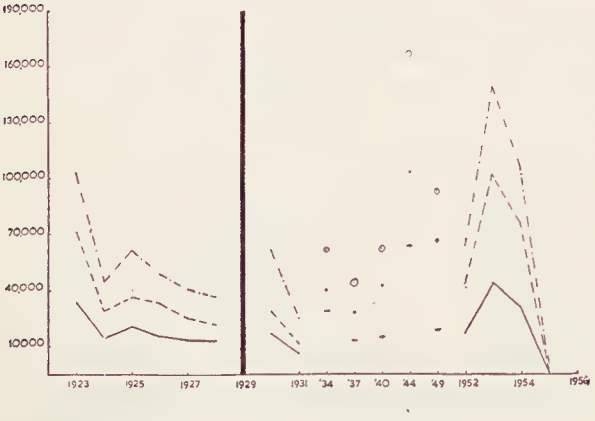

FIG. 2.—Total catch of Brush Possums for the period 1923-52. In this and figs. 3-9 a solid line indicates a closed season or seasons. The years 1946, 1947, 1950 and 1951 all had very low catches, see Table III, and are not shown on this graph. The continuous line indicates the catch of black possums, the broken line the catch of greys and the total catch is shown by the dot-dash line.

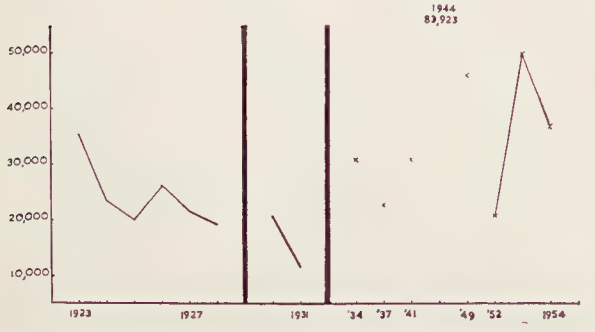

FIG. 3.—Catch per month of open season of Brush Possum for the period 1923-52.

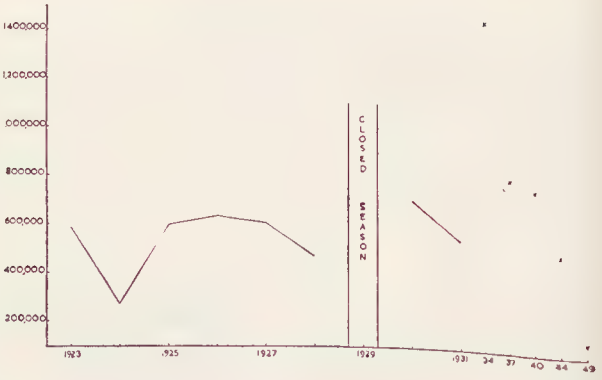

FIG. 4.—Catch of Ringtail Possums for the period 1923-49.

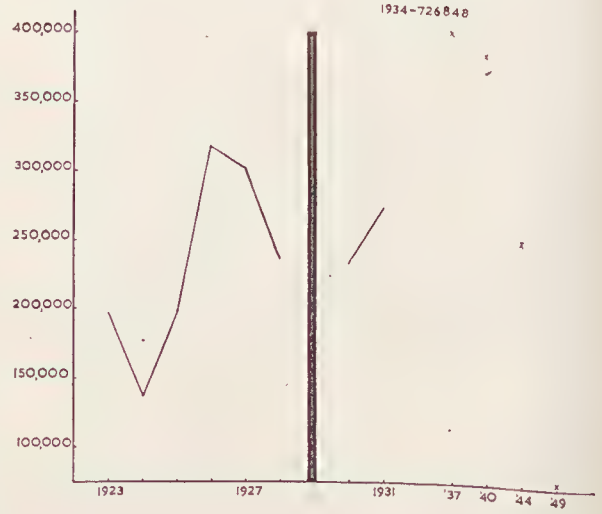

FIG. 5.—Catch per month of open season of Ringtail Possums for the period 1923-49.

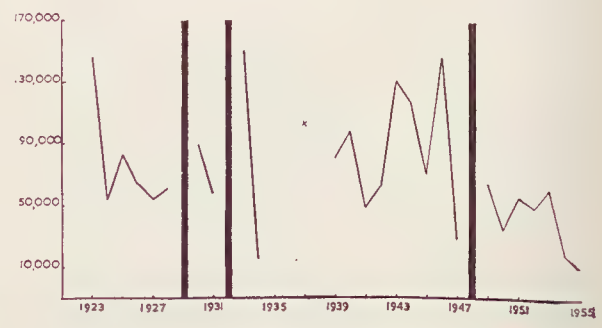

FIG. 6.—Catch of wallaby for the period 1923-52.

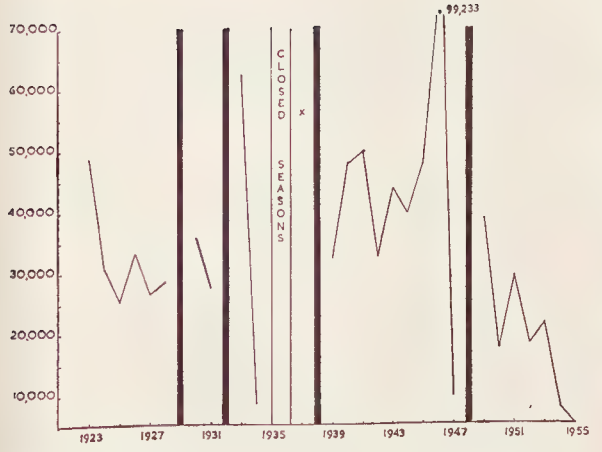

FIG. 7.—Catch per month of open season of wallaby for the period 1923-52.

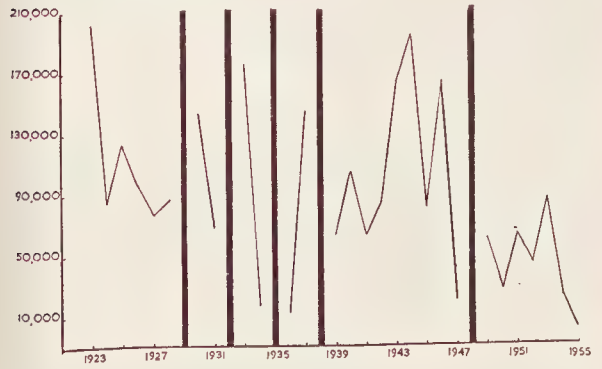

FIG. 8.—Catch of thylogales for the period 1923-52.

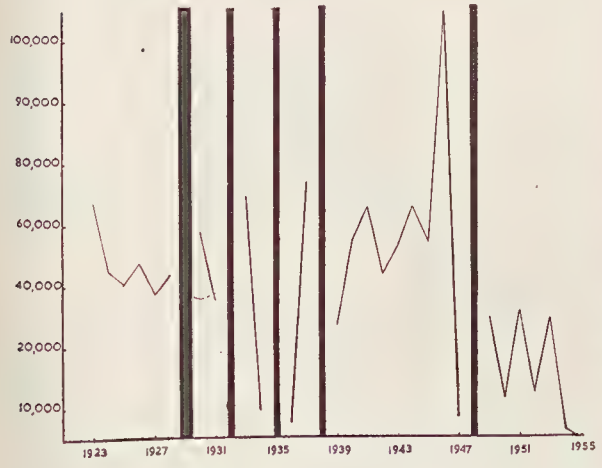

FIG. 9.—Catch per month of open season of thylogales for the period 1923-52.

The total number of pelts taken since 1942 is 4793. The number of licences issued since 1947 is also shown in Table II and these figures have been used to derive the catch per licence.

During the period 1947-52, the average number of pelts obtained per licence issued fell to 4·8. In 1948 there was an increase in the number of men working in the industry but not only was there a decrease in the return per licence but the total number of pelts taken was lower. A shorter period of the open season in this year helped to bolster up the monthly returns of pelts per licence. In 1949 fewer were engaged in the industry yet the return per licence was even lower than before, while the total number of skins taken was very much less. The year 1950 saw a sharp drop in the number of licences issued (5) and there was a recovery in the number of animals caught per licence, but 1951 saw a serious decline in the total number of skins taken as well as in the return per licence. The 1952 open season saw a further decline in this section of the industry. However, in view of the different lengths of time that the season is open each year, it is necessary to reduce the return per licence to a monthly basis. Since 1952 there has been a recovery in the number of pelts taken per licence, and the total of pelts taken has also increased.

The return per licence per month was 0·5 of a pelt higher in 1948 than in 1947. The year following was lower while the 1950 season reached the highest figures since records have been kept, though it must be realized that this figure was achieved by a very much smaller number of men. In 1951 this return showed a serious decline to 9·3 pelts per licence per month, while in 1952 this index was 4·2 pelts per licence per month, but since this date the return per licence has increased to about 20 pelts.

On the figures given above, the position of the water-rat in 1952 might have given rise to grave concern as all the evidence points to serious over-exploitation of the species. Not only had the total catch been falling but the index of yield per individual also fell. This is especially obvious in 1951 when in spite of a slight increase in men employed, the number of skins taken fell by 50 per cent. The extra men actually represent an increase of effort of 20 per cent over the previous year. A decrease of effort of 17 per cent in 1952 saw the index falling by nearly 50 per cent. The situation outlined above gives a false impression of the status of the water-rats. In those years that few rats were trapped the species was numerous and widespread in distribution. I have been informed by skin dealers that there was little demand for pelts during those years so it would appear that the principal factor affecting the catch of *Hydromys* is the economic pressure of demand.

(*b*) The Brush Possum

Records for this species commence in 1923. As noted above, the species is treated in the skin industry as two types—the black and grey. The prices given for the black pelt are greater than those paid for greys. The catch of this species is shown in Table III and figure 2.

The total number of pelts taken since 1923 is 1,062,513. The catch per month of open season is shown in Table VI.

The number of licences issued in 1949, 1950 and 1951 are not known. As noted above, issue of a hunter's licence entitles the holder to take possum, thylogale and wallaby so it is not possible to estimate accurately the number of trappers working in the hunting season.

A feature of the catch per month of Brush Possums has been the remarkable steadiness of the total number of skins trapped. Apart from the years 1923, 1931, 1934, 1944 and 1949 the monthly catch has been in the region of 20,000-30,000 skins (fig. 3). There is very little evidence of any cycle in the variation of numbers of this species and the short period of records with many closed seasons does not give any helpful indications of such a rhythm. The species appears to be in little danger of extermination.

In 1955 the number of animals caught was extremely low. This can be ascribed to the very low price being paid for skins in that year, with a consequent drop in the number of persons engaged in trapping. Although the price paid to trappers for possum skins is not known, all persons interviewed stated that it was not worth their while going after possum, due to the poor reward.

The figures for the number of pelts of Ringtails on which royalties are paid are available from 1923 onwards and are shown in Table V and in figure 4.

The total number of pelts taken since 1923 is 7,409,351. The catch per month of open season is shown in Table VI and figure 5.

The catch per month of open season of this species shows a considerable variation but due to the short period for which records are available, no rhythm can be observed. Prior to 1949, the catch was always greater than 100,000 pelts, in one year even reaching 726,000 pelts. The low catch in 1949 may be due to the condition of the pelts and to a prevailing low price. All Ringtail hunters state that the pelt varies considerably in its quality over a period of years. The trappers with whom I have discussed this problem state that at irregular intervals the Ringtail Possums deteriorate in condition and die off in large numbers. However, Ringtails are numerous throughout the country and the four years closed season has enabled the species to become very plentiful in some areas.

(*d*) Wallaby

The number of wallaby skins taken since 1923 is shown in Table VII and figure 6.

The total number of skins taken since 1923 is 2,039,200. The catch per month of open season is shown in Table VIII and on figure 7.

The number of licences issued to individuals engaged in wallaby hunting is shown in Table IX, together with the average return per licence issued.

(*e*) Thylogale

The number of thylogale skins taken since 1923 is shown in Table X and figure 8.

The total number of skins taken since 1923 is 2,547,529. The catch of thylogales per month of open season is shown in Table X and on figure 9.

The numbers of individuals engaged in this part of the industry cannot be separated from those engaged in the wallaby industry. These numbers, with the return per licence issued are shown in Table XII. The return for the 1949 season was obtained by calculating the average number of licences issued over the three year period.

Since thylogales and wallabies are usually hunted together, the returns for each species must be added together to give the total return to each hunter as in Table XIII.

The return to trappers since 1950 shows a very considerable variation from a maximum 73·1 pelts per licence in 1951 to 37·4 pelts per licence in 1952. There is no purpose to be served by calculating the return per licence per month for 1953-5 since the season has been permanently open over much of the State in those years. The figures do not extend over a sufficiently long period of time to warrant any conclusions being drawn from them.

There is no need for any concern about the immediate future of the *Wallabia* and *Thylogale*. Both species are increasing and in the north-west of the country, where they are present in pest dimensions, a permanent open season has been declared. In other parts of the country the species are plentiful.

Deer

Deer hunting licences are issued at a charge of 2s. 6d. and entitle the holder to take one male deer per day during an open season. The carcase with head attached has to be produced at a police station where it is examined as to maturity. No figures are kept relating to the catch and this species is utilized for sporting purposes only.

MEAT

Several species of Tasmanian mammals are used in the meat trade. The wallaby and thylogale are used to some extent for supplying meat, but there is some difference of opinion as to the appetizing and sustaining value of macropod meat. The hindquarters only are sold, hunters receiving about 1s. per pound weight for them. It is not possible to obtain statistical figures for this aspect of the industry as it is a rather spasmodic and casual business. It is often difficult to transport the meat to the market from the somewhat inaccessible hunting areas. The meat is hung for several days and this greatly increases the danger of it being "blown" by blowflies. In spite of these difficulties, some hindquarters appear in Hobart shops during the open seasons.

The most usual method of preparation of kangaroo meat is for it to be minced, and bacon, ham, potato and seasoning added. This mixture is then fried and served as patties. The end product is very tasty but with so many added flavourings it would be surprising if it were not so. Gould records that kangaroo meat was favoured among early settlers, but this may have been because of the absence of any other meat. One bushman told me that he considered "'roos were good to help you get home but fit for nothing else".

Some bushmen enjoy kangaroo meat, while others consider that "a week of 'roo makes you appreciate mutton". Kangaroo tail soup is considered by some to be a delicacy. Young Thylogale hindquarters roasted on the spit over an open fire are delicious.

Rabbits are eaten extensively throughout Tasmania. The carcases are available from most butchers' and grocers' shops in the towns and cities. The recent introduction of myxomatosis and the poison "1080" has resulted in some decline in the demand for rabbits.

Fig. 10.—The hunting areas of Tasmania.

HUNTING AREAS

(*a*) General

It is possible to gain an estimate of the areas in which most game hunting takes place by the number of hunting licences issued in any particular area.

The duplicates of all hunting licences issued have been examined and the number of licences issued at each issuing centre for the years 1949-1952 inclusive, has been calculated. Tasmania is divided into eight areas (fig. 10) based on geographical and population regions and the number of licences issued in each of the areas, extracted (Table XIV).

From the table it can be seen that the greatest hunting activity takes place in the northern area and the midland area. The north-eastern and north-western areas are considerably hunted but the eastern and western areas are very little exploited.

(*b*) Deer

The most interesting feature of Table XV is the swing in the emphasis of hunting away from the northern to the midland area. In the five years 1947-1951 the number of licences issued in the midland centres was 34, 51, 50, 64 and 95 per cent of the totals issued in the north, ultimately in 1955 becoming almost twice as many as issued in the north. However, these figures present an untrue picture; since there are no deer in the southern area it is a reasonable presumption that licences issued in the south (mostly in Hobart) are used for hunting in the midlands whereas those issued in the northern area are used in that area. By totalling the number of licences issued in the southern and midlands areas, the revised percentages are 66, 81, 89, 93 and 149 per cent, respectively. These figures further show the change in deer hunting from the northern to the midlands area.

POPULATION VARIATIONS

Examination of the available data does not show the presence of any well-defined rhythm in the population numbers of any of the fur-bearing species, though there is a possibility that a 10-11 year sunspot cycle exists as has been shown in other mammals (Elton, 1925). However, there are one or two interesting points to be noted from examination of the monthly kill of animals as shown in figs. 4, 5, 7 and 9. In these figures with the exception of fig. 5, the general pattern of the annual variation in numbers of animals is closely similar. In 1923 a large number were taken, dropping until 1925 when there was a slight increase followed by a further fall. The years 1930-1 showed a sharp drop in numbers of Brush Possums, thylogales and wallaby caught, though the number of Ringtail Possums caught showed a sharp increase.

After 1931, the records for both species of possum are irregular due to frequent closed seasons but both the wallaby (*Wallabia*) and the thylogale catches show a very similar pattern up to 1952. The Brush Possum shows a similar trend during the few years it was allowed to be trapped.

There are two possible explanations of this similarity in catches. The first is that all the four important fur-bearing species are acting in response to some external rhythm-inducing factor or factors resulting in a similar pattern of population density. This explanation does not appear correct as it seems unlikely that four species of different families and of different habits should all respond to a similar stimulus, though it must be born in mind that the species are either herbivorous or largely so (*Trichosurus*).

I have not been able to trace any records of the population of higher animals from different families and of different ecological habits varying in numbers at the same time in response to a similar set of conditions. There is no predator-prey relationship such as can be seen in the Arctic Fox fur industries (Elton, 1925).

The second possibility is that the economic demand for furs is reflected in the effort by trappers. The sharp decline of the catch of pelts during the economic depression years 1930-1 is found in all but one of the fur-bearing species for which records are available. The Ringtail Possum is the exception where there was an increase in the catch of skins in 1932. The Ringtail skin is cheaper than the Brush Possum pelt and poorer economic conditions would lead to a demand for the cheaper material. The low price for *Trichosurus* pelts during 1955 resulted in a record low catch which further supports the theory of economic pressure affecting the industry.

The general pattern of the catch for Brush Possum, kangaroo and wallaby is very similar and even the Ringtail Possum shows a somewhat similar pattern. The absence of complete statistical records of the financial aspect of the industry is to be deplored as it is impossible to correlate the value and demand for furs with the catch and so this possibility must remain a conjecture. It is significant that the variation in catches is so uniform. At the present time (1956) *Wallabia* and *Thylogale* are so common that they have become a pest in certain parts of the State and permanent open seasons operate in the north and east of Tasmania. Poisoning of these species is permitted under special permit. The Brush Possum is very common in some parts, notably the Huon area and there are a lot of Ringtails in the country. None of these species is in danger of over-exploitation at present.

ACKNOWLEDGEMENTS

I am indebted to the Commissioner of Police and Mr. Shirley and Mr. Thompson of the Tasmanian Police Department for access to the records of that department. Prof. H. N. Barber, of the Botany Department, University of Tasmania, kindly allowed me the use of a calculating machine for the numerous calculations involved.

SUMMARY

1. Notes are given on the animals which are exploited in Tasmania, namely the Ringtail Possum, *Pseudocheirus convolutor*, the Brush Possum, *Trichosurus vulpecula*, Ben-

nett's Wallaby, *Wallabia rufogrisea*, the Thylogale, *Thylogale desmarestii* and the water rat, *Hydromys chrysogaster*. The deer, *Dama dama*, is hunted for sporting purposes.

2. The control of the exploitation of Tasmanian mammals is outlined.
3. The number of pelts of each species taken since records became available is given together with, where possible, the return per licence per month of open season.
4. The fur-bearing species are in little present danger of over-exploitation, though a dangerous situation could develop if the demand for furs became great.
5. Most hunting in Tasmania takes place in the northern and midlands areas but an interesting change of locality of deer hunting has taken place from the northern to the midland area.
6. No statistics are available to enable the cash return to hunters to be calculated.

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TABLE I

Number of licences issued for the period 1949-55

	1949	1950	1951	1952	1953	1954	1955
Hunter's licence	785	98	212	156	....	204	323
Private land licence	809	278	407	586	....	460	233
Combined Hunter's and Seller's	665	203	210	139	....	306	59
	2,259	579	829	881	....	970	615

TABLE II

Catch of water-rats for the years 1942-55

Year	No. of skins taken	Duration of open season (months)	No. of licences issued	Catch per licence	Catch per licence per month
1942	41	2	....	....	....
1943	15	2	....	....	....
1944	86	2	No licence returns available		
1945	627	1½	....	....	....
1946	660	1½	....	....	....
1947	1,190	3	21	56·6	18·8
1948	1,010	2	26	38·6	19·3
1949	443	2	14	31·6	15·8
1950	229	2	5	45·8	22·9
1951	112	2	6	18·6	9·3
1952	72	3	5	14·4	4·8
1953	....	3	....	No return	
1954	244	3	4	61·0	20·3
1955	64	3	1	64·0	20·0

TABLE III

The number of Trichosurus *taken during the period* 1923-55

Year	Blacks	Greys	Species total	Season length
1923	34,094	71,874	105,968	3
1924	16,324	30,813	47,137	2
1925	21,326	38,866	60,192	3
1926	17,327	34,210	51,537	2
1927	15,434	27,183	42,617	2
1928	15,197	23,245	38,442	2
1929		Closed		
1930	19,490	30,680	50,170	2½
1931	8,711	14,827	23,538	2
1932				
1933				
1934	21,036	40,419	61,455	2
1935				
1936				
1937	17,810	26,596	44,406	2
1939				
1940	18,318	42,739	61,057	2
1941				
1942				
1943				
1944	63,221	104,262	167,847	2
1945				
1946	....	355	355	1½
1947	33	99	132	3
1948		Closed		
1949	22,792	68,023	90,815	2
1950	34	38	72	2
1951	39	1	40	2
1952	18,186	43,171	61,357	3
1953	45,829	103,623	149,452	3
1954	31,950	78,340	110,290	3
1955	57	14	71	4½

TABLE IV

Number of Trichosurus *pelts taken per month of open season for the period* 1923-55

Year	Length of season in months	Blacks	Greys	Total
1923	3	11,365	23,958	35,323
1924	2	8,162	15,406	23,568
1925	3	7,109	12,955	20,064
1926	2	8,663	17,105	25,768
1927	2	7,717	13,591	21,308
1928	2	7,598	11,628	19,226
1929	....	....	....	....
1930	2½	7,796	12,272	20,068
1931	2	4,355	7,414	11,769
1932	....	....	....	....
1933	....	....	....	....
1934	2	10,518	20,209	30,727
1935	....	....	....	....
1936	....	....	....	....
1937	2	8,905	13,298	22,203
1941	2	9,159	21,369	30,528
1944	2	31,610	52,313	83,923
1949	2	11,396	34,011	45,407
1952	3	18,186	43,171	61,357
1953	3	15,276	34,541	49,817
1954	3	10,650	26,113	36,763
1955	4½	14	3	17

TABLE V

Total number of Pseudocheirus *pelts taken during the period* 1923-52

Year	No. of Skins	Length of Season
1923	587,179	3
1924	276,261	2
1925	596,526	3
1926	634,620	2
1927	603,863	2
1928	472,260	2
1929	Closed	
1930	701,059	3
1931	544,077	2
1932		
1933		
1934	1,453,697	2
1935	Closed	
1936	Closed	
1937	804,701	2
1938	Closed	
1939	Closed	
1940	773,277	2
1941	Closed	
1942	Closed	
1943	Closed	
1944	504,745	2
1945	Closed	
1946	Closed	
1947	Closed	
1948	Closed	
1949	158,145	2
1950	Closed	
1951	Closed	
1952	Closed	

TABLE VI

Catch of Pseudochirus *per licence per month of open season during the period* 1923-49

Year	Length of season in months	Catch per month
1923	3	195,726
1924	2	138,130
1925	3	198,842
1926	2	317,310
1927	2	301,931
1928	2	236,130
1929	Closed	Closed
1930	3	233,606
1931	2	•272,038
1934	2	726,848
1937	2	402,355
1940	2	336,638
1944	2	252,372
1949	2	79,072

TABLE VII

The number of wallaby skins taken during open seasons for the period 1923-55

	Year	No. of skins	Length of season
	1923	146,236	3
	1924	61,559	2
	1925	75,979	3
	1926	66,114	2
	1927	53,471	2
	1928	57,746	2
King Is.	1929	3,399	3
	1930	189,571	2½
	1931	54,685	2
King & Fl.	1932	11,365	3
	1933	150,796	2½
	1934	17,121	2
King & Fl.	1935	5,807	3
King & Fl.	1936	5,390	3
King & Fl.	1937	112,182	2
King & Fl.	1938	3,953	3
	1939	80,004	2½
	1940	94,692	2
	1941	49,850	1
	1942	64,581	2
	1943	130,426	3
	1944	118,621	3
	1945	70,195	1½
	1946	148,849	1½
	1947	29,728	3
King & Fl.	1948	23,580	2
	1949	67,374	2
	1950	34,294	2
	1951	58,794	2
	1952	54,468	3
	1953	64,780	3
	1954	22,690	3
	1955	10,900	4½

TABLE VIII

Number of Wallabia *caught per month of open season for the period* 1923-55.

Year	Length of Season in months	Catch per month	
1923	3	48,745	
1924	2	30,779	
1925	3	25,326	
1926	2	33,057	
1927	2	26,735	
1928	2	28,873	
1929	3	1,133	King Is. only
1930	2½	35,828	
1931	2	27,342	
1932	3	3,788	King & Flinders Is.
1933	2½	62,266	
1934	2	8,560	
1935	3	1,936	King & Flinders Is.
1936	3	1,799	King & Flinders Is.
1937	2	56,091	
1938	3	1,318	King & Flinders Is.
1939	2½	32,001	
1940	2	47,346	
1941	1	49,850	
1942	2	32,290	
1943	3	43,475	
1944	3	39,540	
1945	1½	47,797	
1946	1½	99,233	
1947	3	9,909	
1948	2	11,790	King & Flinders Is.
1949	2	38,687	
1950	2	17,147	
1951	2	29,397	
1952	3	18,156	
1953	3	21,593	
1954	3	7,563	
1955	4½	2,422	

TABLE IX

Average returns of skins to Wallabia *professional hunters per licence issued per month of season* 1950-55.

Year	No. of licences	Return per licence	Return per licence per month
1950	579	59·2	29·6
1951	827	70·9	35·5
1952	881	61·9	20·6
1953			
1954	306	74·1	24·7
1955	59	184·9	41·0

TABLE X

The number of thylogale skins taken since 1923.

Year	No. of Skins	Length of Season	
1923	201,365	3	
1924	88,441	2	
1925	121,245	3	
1926	94,531	2	
1927	75,402	2	
1928	87,944	2	
1929 (K.I. only)	19,665	3	
1930	142,203	2½	
1931	69,950	2	
1932 (K.I. only)	10,250	3	
1933	172,219	2½	
1934	18,358	2	
1935 (K.I. & Fl. Is.)	7,386	3	
1936	14,188	3	
1937	146,445	2	
1938 (K.I. & Fl. Is.)	5,739	3	
1939	65,228	2½	
1940	106,650	2	
1941	62,335	1	
1942	86,918	2	
1943	162,832	3	
1944	192,405	3	
1945	80,510	1½	
1946	162,431	1½	
1947	19,224	3	
1948	23,161	2	K.F.
1949	59,206	2	
1950	27,324	2	
1951	62,412	2	
1952	44,611	3	
1953	88,423	3	
1954	20,563	3	
1955	7,956	4½	

TABLE XI

Catch of thylogale for month of open season for period 1923-55.

Year	Length of Season in Months	Catch	
1923	3	67,122	
1924	2	44,220	
1925	3	40,415	
1926	2	47,265	
1927	2	37,701	
1928	2	43,972	
1929	3	6,555	King Island
1930	2½	56,881	
1931	2	34,875	
1932	3	3,416	King & Flinders Is.
1933	2½	68,887	
1934	2	9,179	
1935	3	2,462	King Island
1936	3	4,729	
1937	2	73,223	
1938	3	1,913	King & Flinders Is.
1939	2½	26,091	
1940	2	53,316	
1941	1	62,335	
1942	2	43,459	
1943	3	52,943	
1944	3	64,135	
1945	1½	53,673	
1946	1½	108,287	
1947	3	6,408	
1948	2	11,580	King & Flinders Is.
1949	2	29,603	
1950	2	13,662	
1951	2	31,206	
1952	3	14,870	
1953	3	29,474	
1954	3	6,854	
1955	4½	1,768	

TABLE XII

Return per licence per month of open season to thylogale hunters for the period 1949-55.

Year	No. licences issued	Return per licence	Return per licence per month
1949	763	50·7	25·3
1950	579	47·2	23·6
1951	829	75·3	37·6
1952	881	50·7	16·8
1953			
1954	306	67·2	
1955	59	134·8	

TABLE XIII

Total return to thylogale and wallaby hunters 1950-2

	1950	1951	1952
Wallaby return per licence	59·2	70·9	61·9
Thylogale return per licence	47·2	75·3	50·7
TOTAL	106·4	148·2	112·6
Wallaby return per licence per month	29·6	35·5	20·6
Thylogale return per licence per month	23·6	37·6	16·8
TOTAL	53·2	73·1	37·4

TABLE XIV

Number of licences issued in each hunting area of Tasmania for the period 1949-52.

	1949	1950	1951	1952	Total
Northern Area	437	143	204	236	1,020
Eastern Area	74	23	23	41	161
Southern Area	207	49	58	76	390
Midland Area	382	120	168	241	911
N.W. Area	208	56	151	123	538
N.E. Area	373	186	115	121	795
Western Area	84	30	24	31	169
Islands	41	39	73	50	203

TABLE XV

Number of deer hunting licences issued at various centres in Tasmania for the period 1947-1955.

Area	1947	1948	1949	1950	1951	1952	1953	1954	1955
Northern	117	137	195	200	184			210	281
Eastern	11	13	23	36	10			47	68
Southern	37	40	73	59	99			190	219
Midlands	41	71	99	127	175			428	481
TOTAL	208	261	390	422	468			825	1,047

THE PROBLEM OF THE QUARTZ DOLERITES: SOME SIGNIFICANT FACTS CONCERNING MINERAL VOLUME, GRAIN SIZE AND FABRIC

By

Germaine A. Joplin

Australian National University, Canberra

(With 14 text figures and 5 tables)

Appendix

THE VARIATION OF DENSITY AND MAGNETIC PROPERTIES

By

J. C. Jaeger

Australian National University, Canberra

(With 5 text figures)

(*Communicated by Professor S. Warren Carey*)

INTRODUCTION

The problem of the quartz dolerites has been attacked by a number of methods, yet much remains to be discovered regarding the differentiation of these rocks.

Chemical methods and mineralogical studies, particularly with regard to the pyroxenes, have thrown much light upon the problem, but the extreme uniformity of the dolerites still remains unexplained, and makes the matter of attack on their genesis difficult.

The Tasmanian dolerites have been studied fairly exhaustively by chemical methods (Edwards, 1942), though little serious detailed work has yet been done on their mineralogy. Recently the problem has been attempted on a physical basis (Jaeger and Joplin, 1955) and measurements of magnetic intensity, magnetic susceptibility and density have indicated differences in rock type which are not readily apparent either in the field or by using the normal microscopic methods.

On the results of this physical work a method of differentiation was expounded, and though no detailed mineralogical work was attempted, microscope examination indicated that there was nothing to suggest that this type of differentiation could not have occurred. Whilst engaged on these examinations, however, the present writer was struck by differences in fabric and grain size within a single microscope section and it was thought that such observations were highly significant in discussing the cooling history. This communication, therefore, is a compilation of such data, together with a series of modal analyses, and a brief discussion on the significance of these observations with regard to magmatic differentiation.

The writer is indebted to Professor J. C. Jaeger for supplying the appended data on density and magnetic properties, and for much helpful discussion. She would also like to thank Messrs. A. Spry and R. Ford and Dr. Williams of the Department of Geology, University of Tasmania as well as Mr. G. Hale of the Hydro-electric Commission of Tasmania for taking her to many places of interest in the Hobart area and in the Upper Derwent Valley. The author also wishes to thank Professor S. W. Carey for his help for communicating the paper.

FIELD OCCURRENCE

Twelvetrees and Petterd (1899) and Edwards (1942) have remarked on the extreme uniformity of the Tasmanian dolerite sills in the field, although Edwards has mentioned the occurrence of chilled margins and of occasional pegmatites. Nevertheless, Edwards' own chemical work has shown that quite considerable differentiation has occurred, and, as noted above, physical measurements (Jaeger and Joplin, 1955) have also indicated marked differences. Furthermore, micrometric analysis reveals much variation of mineral volume among the limited number of constituent minerals.

Recent work by Tasmanian geologists indicates that many of the so-called sills show transgressive relations to the sediments and thus should be termed "sheets".

Recently a short field trip was undertaken to examine quarry, road and shore sections in some detail in an endeavour to observe any field evidence of differences that had been noted in the laboratory. Most of the exposures examined occurred in and about Hobart and in the Upper Derwent Valley.

Brief notes on these sections are given below and it is concluded that the sills commonly show chilled margins of varying width, that pegmatites, occurring as discrete veins or schleirren or, more commonly, as elongated patches merging into the normal dolerite, are developed as a rule not far below the upper chilled margin. Pegmatites were not noted near lower contacts, but careful examination revealed finer grained veins or patches in some places. In general, the normal dolerite is extremely uniform. Calcite, and sometimes pyrite and zeolites are present along joint planes, especially in the region immediately below the upper chilled margin, and in one case fine basaltic veins were seen to intersect the upper marginal phase.

Unfortunately the cuttings on the road up Mount Wellington are somewhat weathered and in places covered by talus. Good exposures occur for the first 200 feet above the base and this is followed by about 80 feet covered by talus. In this latter section a junction betwen very fine dolerite and medium-grained dolerite was observed. The block showing this junction was not *in situ*, though the texture of the coarser type indicated that it had not travelled far and certainly had not come from the upper portion of the sill. The finer grained rock contained a larger proportion of ferromagnesian mineral, and as the junction was not sharp it suggested a vein-like mass injected before the host rock had completely solidified.* At 280 feet above the base the dolerite is exposed *in situ* in a steep cutting but is overlain by talus at a short distance from the road. From then on, the road section is covered intermittently to about 800 feet above the base, after which exposures are good to the summit of the mountain. There is a marked change in the texture of the rock above about 400 feet, the upper portion being much coarser and a little lighter in colour.

On the cliff section at Blackmans Bay the top of a sill is exposed. The marginal dolerite is fine to medium grained and is cut by small veins of very fine dolerite (basalt). At the base of the cliff a small storm beach is made up of large boulders of medium-grained dolerite which contain veins and patches of coarse pegmatite. It is assumed that these have been torn from a submerged rock-platform nearby and represent a slightly lower level of the sill.

In one of the quarries on Proctors Road, in the Mount Nelson sill, two coarse pegmatite veins, parallel to one another and connected by a small cross vein, intersect normal dolerite. These masses are presumably parallel to the upper contact which is not exposed in this quarry.

In the Upper Derwent area, near Tarraleah, several small quarries expose the upper contacts of sills. One of these shows small masses of pegmatite near the top of the sill, but in other quarries, and in the diversion tunnel through dolerite, the rock appears to be extremely uniform.

In the Great Lake area near the collar of bore 5001, it is reported that there is a good deal of pegmatite amongst surface exposures. Petrographical and magnetic evidence suggests that the collar is not far below the top of the sill, though there is no direct field evidence that this is so. It was stated by Jaeger and Joplin (1955) that sediments were *in situ* nearby, but unfortunately this statement was made in error and we would like to take this opportunity of correcting it.

MODAL ANALYSES

Bore cores provide most of the material for this study, and although they have been carefully logged the full thickness of the sills, or the exact part of the intrusion penetrated, is rarely known. In some cases upper or lower contacts have been encountered, but at present there is no record of any large sill showing both contacts. The mass examined by Jaeger and Joplin (1955) represents 1050 feet of dolerite, and although guesses were made as to the total thickness of the intrusion its exact thickness still remains in doubt; furthermore, some of the Tasmanian geologists now raise the doubt as to whether it is in fact a sill or a vertical feeding channel.

In an attempt to throw some further light on these questions, it is assumed that the well-documented Palisade sill represents the normal behaviour of such intrusions, and modal analyses from a number of sections (Walker, 1940) have been plotted in figs. 1-4. These show that there is a very definite and constant pattern, and that the amounts of pyroxene and plagioclase are nearly equal for the first 100 feet above the base. In the first 10 or 20 feet plagioclase may exceed pyroxene, but only by a comparatively small amount. Both minerals decrease in the region of the olivine ledge and pyroxene always exceeds plagioclase at this level. Immediately above the olivine layer both minerals increase again with pyroxene still a little in excess of felspar. Above 100 feet there is a sudden marked increase in plagioclase and a concomitant decrease in pyroxene until the level of from 500 to 700 feet is reached. Above this the amounts of the two minerals gradually approach one another again until they are equal, or only a few volumes per cent apart, at the upper contact.

Olivine occurs at both upper and lower contacts and reaches a maximum at the olivine ledge from 50-80 feet above the base. The mesostasis, which in this sill consists of a micropegmatitic intergrowth of quartz and felspar, is never abundant but gradually increases from immediately above the olivine-rich layer until it reaches a maximum of some 7 per cent within 50-100 feet of the upper contact. There is a slight enrichment of iron ore at the lower contact and a slight, though abrupt, decrease in the first few feet. The iron ores then slowly and steadily rise to a maximum at much the same position as that attained by the mesostasis.

* A similar vein occurs at 410 feet above the base of the borehole 5001 and is figured in fig. 12*c*.

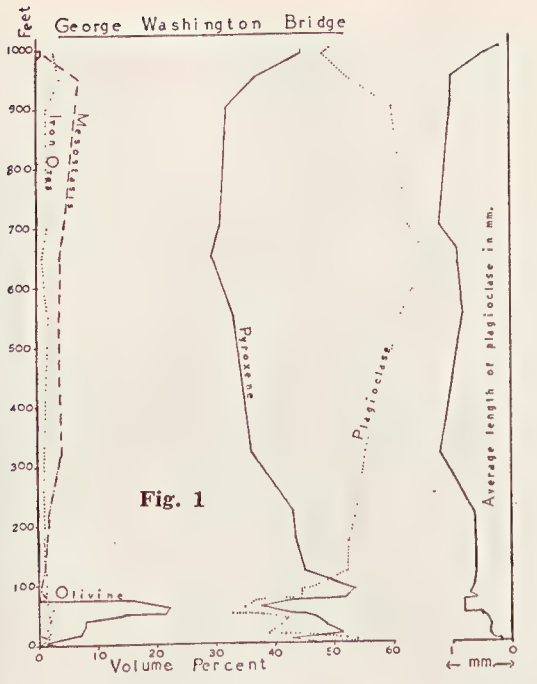

Fig. 1

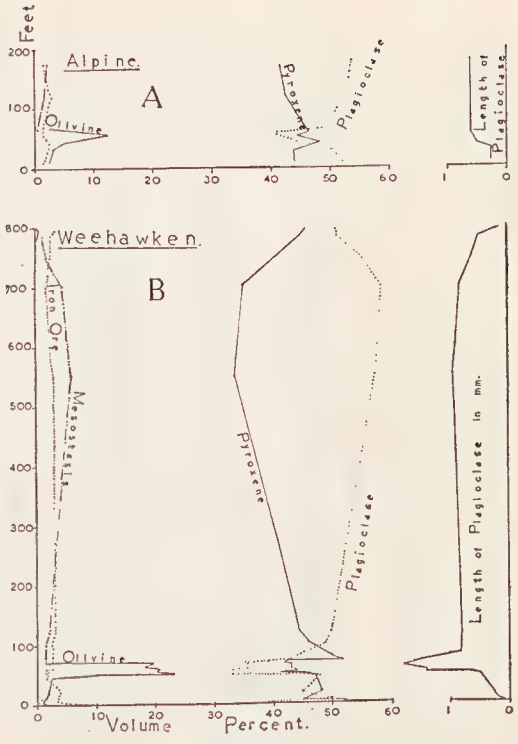

Fig. 3

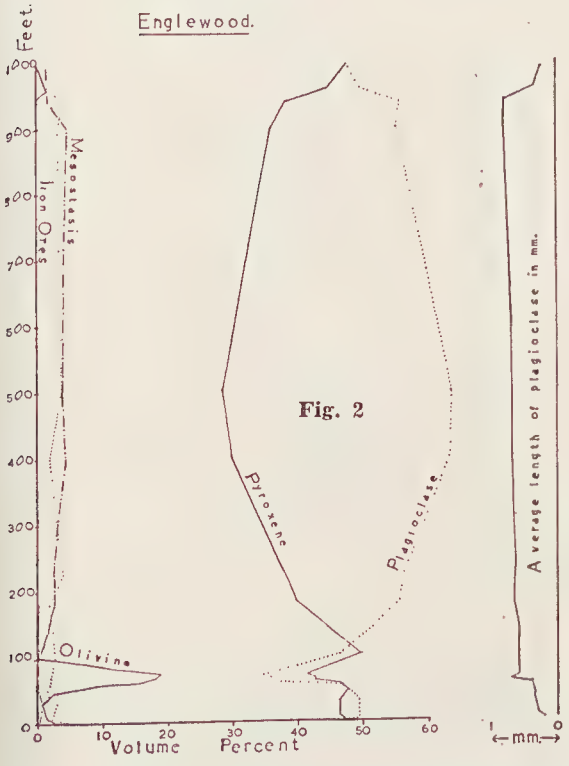

Fig. 2

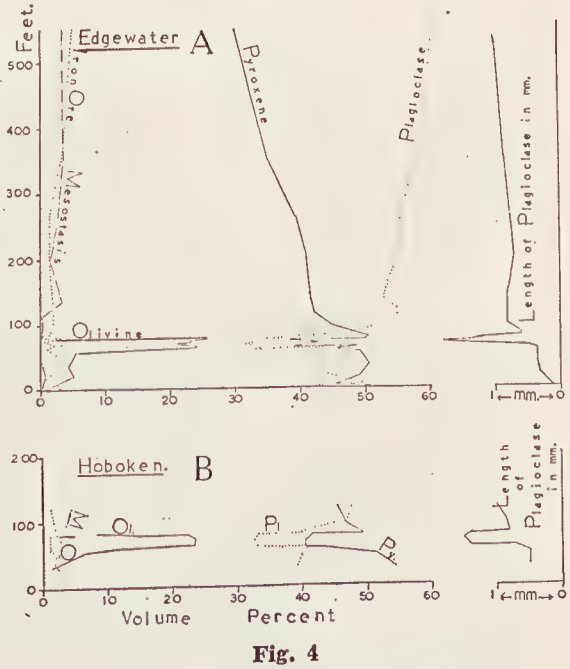

Fig. 4

FIGS. 1-4.—Plots of micrometric analyses of various sections of the Palisade sill, New Jersey.

TABLE I
Mount Wellington

Height above base of Sill	Pyroxene	Plagioclase	Mesostasis	Chlorite	Quartz	Orthoclase	Iron Ores	Average length of Plagioclase		Average Diameter of Plagioclase		
1140′ ..	15.8	41.6	27.8	10.0	0.6	—	3.9	—	—	0.18	—	0.45
1120′ ..	16.3	44.7	25.0	6.9	1.9	—	5.1	—	—	0.18	—	0–72
1100′ ..	13.9	38.9	38.9	5.2	2.4	—	1.6 *e*	—	—	0.04	—	1.20
1095′ ..	23.7	38.3	24.4	6.5	—	—	2.9	—	—	0.22	—	0.54
1080′ ..	6.6	47.8	40.1	3.0	0.3	—	2.0	—	—	0.18	—	0.72
1065′ ..	12.6	43.4	29.2	9.9	nd	—	4.9	—	—	0–27	—	0.90
1050′ ..	14 2	47.3	27.4	8.7	0.5	—	1.9	—	—	0.29	—	0.77
1045′ ..	7.9	43.2	24.1	19.5	0.8	—	4.2 *e*	0.7	1.3	0.29	—	0.63
1025′ ..	20.7	41.6	26.5	7.6	1.4	—	2.1	0.7	1.2	0.29	—	0.72
1020′ ..	16.7 *a*	42.2	28.6	10.4	—	—	2.1	0.7	1.0	0.29	—	0.54
980′ ..	13.0	47.2	29.6	7.8	—	—	2.5	0.7	—	0.27	—	0.54
975′ ..	12.7	51.5	25.8	7.9	—	—	2.0	0.3	2.0	0.22	—	0.77
965′ ..	21.3	46.4	21.9	5.4	—	—	5.0	0.5	1.4	0.23	—	0.66
945′ ..	20.5	47.1	24.4	4.4	0.6	—	3.0	0.5	0.9	0.22	0.36	0.54
930′ ..	19.5	46.7	20.9	8.8	—	—	4.0	0.6	0.7	0.27	—	0.54
830′ ..	8.3	50.6	32.3	6.6	—	—	2.2	0.3	0.9	0.22	—	0.59
800′ ..	17.1	46.6	26.8	6.9	—	—	2.5	0.6	—	0.22	—	0.72
680′ ..	13.2	54.4	20.6	9.6	—	—	2.1	0.5	0.9	0.20	—	0.39
650′ ..	14.1	54.7	23.8	5.7 *b*	—	—	1.6	0.6	1.0	0.20	—	0.77
460′ ..	17.2	57.0	21.8	1.2	1.3	—	1.2	0.6	0.7	0.20	—	0.54
430′ ..	18.9	57.4	19.7	1.9	—	—	1.9	0.6	1.0	0.16	—	0.27
430′ ..	23.1	46.6	22.4	2.5	1.3	—	3 9	0.5	0.7	0.22	—	1.15 *c*
425′ ..	25.2	46.1	22.8	3.0	—	—	2.7	0.3	0.6	0.11	—	0.39
395′ ..	41.9	41.2	15.4	—	0.2	—	1.1	0.9	1.0	0.18	—	0.81
390′ ..	32.7	44.3	21.5	0.8	—	—	0.7	0.3	0.6	0.14	—	0.36
382′ ..	26.0	51.2	15.7	3.6	—	—	3.4	0.3	0.6	0.14	—	0.72
376′ ..	25.2	50.7	18.5	3.6 *b*	—	—	1.7	0.2	0.6	0.20	—	0.36 *c*
370′ ..	43.8	43.2	12.1	—	—	—	0.8	0.2	0.7	0.07	—	0.34
366′ ..	33.5	47.0	15.5	1.6 *b*	—	—	2.4	0.7	0.9	0.16	—	0.54
335′ ..	47.6	35.8	12.0	2.8	—	—	1.8	0.7	0.9	0.16	—	0.40 *d*
330′ ..	38.2	42.7	17.7	0.9	—	—	0.7	0.4	0.6	0.13	—	0.45 *c*
324′ ..	51.1	37.0	9.3	1.4	—	—	1.1	0.7	—	0.13	—	0.30 *c*
320′ ..	35.8	46.7	15.9	0.1 *b*	0.1	—	1.1	0.7	—	0.13	—	0.36 *c*
291′ ..	46.3	41.3	11.4	0.1 *b*	—	—	1.0	0.9	—	0.14	—	0.29 *c*
280′ ..	44.7	41.2	12 1	0.2	—	—	1.7	0.5	0.6	0.11	—	0.27
280′ ..	49.8	35.2	14.2	—	—	—	0.8	0.7	0.9	0.11	—	0.23
198′ ..	47.8	42.9	6.5	1.0	—	—	1.3	0.3	0.9	0.09	—	0.22
197′ ..	45.0	43.7	6.5	0.3	2.1	0.9	1.4	0.3	0.7	0.09	—	0.29
194′ ..	41.8	46.4	5.3	1.3	2.6	0.5	1.9	0.5	0.9	0.11	—	0.20
180′ ..	36.7	51.2	9.3	1.1	0.6	—	1.3	0.4	1.0	0.09	—	0.30
155′ ..	43.3	43.3	2.7	0.7	7.1	1.0	1.7	0.3	0 5	0.07	—	0.27
149′ ..	45.4	45.6	2.2	0.3	4.2	0.6	1.7	0.2	0.7	0.09	—	0.36
144′ ..	50.0	37 6	2.8	0.8	5.2	2.7	1.6	0.2	1.5	0.07	—	0.36
140′ ..	41.6	49.9	3.3	2.7 *b*	—	—	2.3	0.2	1.2	0.09	—	0.36
128′ ..	52.7	37.6	3.2	0.2 *b*	3.5	1.3	1.6	0.2	1.1	0.09	—	0.20
119′ ..	45.3	44.1	3.8	0.8 *b*	4.5	—	1.3	0.5	1.2	0.05	—	0.14
102′ ..	43.1	35.5	4.8	1.9	11.8	—	2.8	0.2	—	0.05	—	0.20
90′ ..	49.4	35.7	5.3	2.9	3.6	0.6	2.2	0.2	—	0.05	—	0.54
79′ ..	42.0	35.4	4.5	—	9.5	4.9	3.5	0.3	—	0.07	—	0.20
70′ ..	50.3	37.7	3.3	1.8	2.3	0.7	3.7	0.2	0.3	0.05	0.12	0.20
61′ ..	45.8	35.2	5.1	1.4	6.1	2.9	3.4	0.3	0.4	0.05	0.11	0.36
55′ ..	43.1	40.9	4.7	2.8	1.1	1.7	5.6	0.2	0.4	0.05	—	0.18
51′ ..	48.5	34.5	4.3	3.8	3.5	—	5.3	0.3	—	0.05	0.11	0.18
47′ ..	48.2	32.3	11.3	2.8	1.2	—	4.0	0.4	—	0.09	—	0.27
43′ ..	47.4	35.1	7.2	2.7	2.8	0.9	3.7	0.1	0.5	0.09	—	0.23
33′ ..	46.2	30.2	12.1	8.1 *f*	0.2	0.5	2.4	0.1	0.3	0.02	0.07	0.18
32′ ..	46.2	32.0	14.7	2 0	—	—	5.0	0.3	—	0.07	—	0.18
30′ ..	48.7	34.4	2.5	1.8	6.3	1.7	4.7	0.1	0.3	0.02	0.07	0.30
27′ ..	44.3	30.6	17.7	3.0	—	—	4.3	0.1	1.0	0.02	—	0.11
23′ ..	46.9	29.1	17.7	1.4	0.8	—	4.0	0.1	0.3	0.05	—	0.27
18′ ..	47.3	32.0	15.8	—	0.5	—	4.5	0.2	0.3	0.04	—	0.18
12′ ..	47.8	35.2	13.9	—	0.03	—	2.7	0.3	0.5	0.05	—	0.13
6′ ..	46.8	28.4	19.0	—	—	—	5.6	0.3	—	0.01	0.05	0.27
3′ ..	40.0	31.6	17.6	3.8 *f*	—	—	6.9	0.2	0.3	0.03	0.07	0.14
1′ ..	38.3	35.4	18.9	0.5	—	—	6.8	0.2	0.3	0.01	0.09	0.36
0′ ..	41.8	30.2	17.3	0.4	1.2	—	9.0	0.2	0.3	0.03	—	0.07

Anal. G. A. JOPLIN

a Small amount of Hornblende counted as Pyroxene.
b Small amount of Biotite, mainly chloritized, and counted as chlorite.
c Larger Plagioclase zoned.
d Larger Plagioclase tabular and interstitial.
e Including small amount of Pyrite.
f Pyroxene partly chloritized.

It seems obvious that Walker made micrometric measurements of normal types of dolerite only and that schleirren and veins were deliberately excluded.

If the same method and scale is used in plotting the modal analyses of some of the Tasmanian dolerites a very similar pattern emerges. Actually a greater number of analyses have been used in the Tasmanian sections, they are more closely spaced and the material was not selected to illustrate the magmatic differentiation but rather to study odd magnetic properties, so it is probable that slides have been made of schlieren and veins

which are not very apparent in the small bore core (diameter ¾"). As indicated by the work of Edwards (1942) there is no evidence of any ferromagnesian ledge, though in the Mount Wellington sill there is an enrichment of magnesian pyroxene at the 280 foot level.

Apart from the scarcity or absence of olivine in the Tasmanian sills the greatest difference between them and the Palisade lies in their greater abundance of mesostasis, which attains a value of about 30 per cent of the total volume in a rock near the top of Mount Wellington. The mesostasis of these rocks consists either of a micropegmatic intergrowth of quartz and felspar, of small quartz grains surrounded by chlorite, of chlorite alone or most commonly of indefinite felspathic material. Much of this felspar is potassic and it may occur as irregular grains or as radiating masses (figs. 11*c*, 12*b*, 13*a*) often pierced by long slender needles of plagioclase which appear to be outgrowths from adjacent plagioclase laths (fig. 11 *c*). Small quantities of biotite and grains of iron ore commonly occur in the mesostasis, the latter being more abundant in the upper more acid region of the sill and occurring as minute grains around the bordering minerals or in larger grains moulded on felspar and pyroxene. (Figs. 11 *b*, and *c*, 12 *b* and *c*, and 13 *b*.)

As the base of the Mount Wellington sill is exposed and the mass is of comparable thickness to the Palisade sill, it was thought desirable first to compare this section with the New Jersey example. Most of the material was collected by Professor Jaeger using an aneroid barometer, and though at the time of collecting there were no bench-marks on the mountain and no exact corrections were made for barometric variations, the relative positions of specimens are quite definite.

Reference to fig. 5 shows that the general pattern of what is taken to be the typical example (the Palisade) is apparent, though slightly masked by minor variations. Examination shows that the amounts of plagioclase and of pyroxene remain fairly close together until the level of 400 feet is reached, but more critical examination reveals that, except for three analyses which may represent veins, there is a falling off of pyroxene and an increase of plagioclase at about the 300 foot level. It may be significant that the magnesian-rich dolerite, which Edwards regards as the most basic part of the sill, occurs at 280 feet and that immediately above the ultrabasic olivine ledge of the Palisade sill plagioclase becomes excessive over pyroxene. Unlike the Palisade Sill, however, pyroxene exceeds plagioclase at the actual contact, though this may be exceptional since Mr. A. Spry of the University of Tasmania reports that a micrometric measurement made by one of his students showed the reverse and Edwards found 45 per cent of plagioclase at the margin. Immediately above the magnesia-rich layer there is a general decrease of pyroxene and an enrichment of plagioclase, although this is not clearly indicated until the 400 foot level is reached. As pointed out in the notes on the field occurrence a fine grained darker vein was encountered in a boulder below this level and it is possible that the three rocks which appear abnormal between 280 feet and 400 feet may represent such veins or segregation patches.

FIG. 5.—Plot of micrometric analyses of Mount Wellington sill, Tasmania.

Above 400 feet the amounts of pyroxene and plagioclase diverge and their behaviour is exactly similar to that of the minerals of the Palisade sill, except that both tend to be slightly lower as the amount of mesostasis increases sharply above 200 feet. The quantity of iron ores is greater in the Tasmanian rock, though the behaviour of the curve is exactly similar. Chlorite, quartz and orthoclase have been added to the mesostasis in plotting these graphs except where it is indicated that chlorite is replacing pyroxene.

Reference to fig. 6 shows that Bore 5001 follows the same general pattern, and, except for a greater number of possible veins and segregations (deliberately chosen because of their magnetic properties) * is closely comparable to the Mount Wellington sill above the 300 foot level. Furthermore, the amounts of pyroxene and plagioclase are drawing closer together near the top of the bore, thus suggesting that this level may be a higher one than that represented by the top of Mount Wellington, and is in fact near the actual top of the intrusion. These observations suggest that 5001 is a normal sill and that its base may be reached at another 300 feet.

* Reference to Jaeger and Joplin (1955) figs. 1 and 3, shows that there is a peak in the intensity of magnetization and in the magnetic susceptibility at 949 feet, that is at 101 feet above the base of the bore. Figure 6 of the present paper shows a marked increase in the amount of mesostasis at this point. The mesostasis usually carries minute grains of iron ore too small for measurement as such.

TABLE II

Bore Core 5001

Height above bottom of bore	Depth from surface	Pyroxene	Plagioclase	Mesostasis	Chlorite	Quartz	Iron Ores	Average length of Plagioclase		Average diameter of Plagioclase		
1049′	1′	33.2	41.0	21.6	2.6	—	1.7	0.6	0.7	0.05	—	0.39
1032′	18′	28.1	43.6	21.1	1.8	2.5	2.7	0.4	0.6	0.14	—	0.36
1000′	50′	28.9	31.8	23.8	10.0	—	5.3	0.2	—	0.45	—	0.80
944′	106′	33.5	43.0	19.2	1.9	—	2.3	0.5	1.5	0.18	0.54	1.37
902′	148′	15.7	46.3	24.9	6.0	3.1	3.8	0.6	—	0.11	—	0.54
897′	153′	6.0	43.7	37.0	8.7	—	4.8	0.3	0.4	0.09	—	0.27
850′	200′	21.5	45.8	18.6	10.7	—	3.3	0.4	1.0	0.18	—	0.72
769′	281′	16.6	44.5	18.3	9.2	—	9.2	0.6	1.0	0.18	—	0.72
754′	296′	16.4	46.9	26.1	7.4	—	3.0	0.5	0.7	0.20	—	0.48
741′	309′	17.7	36.7	23.6	12.1	1.5	8.2	0.7	—	0.25	—	1.71
707′	343′	27.7	39.3	17.5	11.5	—	3.8	0.6	—	0.29	—	0.90
653′	397′	27.7	34.3	19.5	13.8	—	4.5	0.5	—	0.25	—	0.54
650′	400′	20.8	35.7	23.7	12.7	—	7.0	0.3	0.7	0.21	—	0.37
639′	411′	26.0	35.2	26.8	6.8	—	5.1	0.5	0.6	0.22	—	0.37
570′	480′	24.7	45.6	20.5	6.5	—	3.0	0.3	0.5	0.23	—	0.90
537′	513′	12.8	50.6	25.5	5.2	—	5.8	0.5	—	0.22	—	0.27
450′	600′	6.4	56.7	21.5	13.7	—	1.5	0.3	1.0	0.13	—	0.36
438′	612′	24.4	49.3	19.3	3.8	—	3.1	0.6	—	0.14	—	0.54
426′	624′	11.8	48.9	31.7	4.3	—	3.3	0.3	0.9	0.27	—	0.39
409′	641′	20.6	47.2	20.6	—	—	11.6	0.6	0.7	0.22	—	0.66
383′	667′	33.5	42.1	19.9	1.8	—	2.5	0.5	0.6	0.23	—	0.45
371′	679′	27.1	49.6	20 6	—	—	2.6	0.3	—	0.23	—	0.36
359′	691′	35.9	42.4	16.0	1.4	—	4.3	0.5	—	0.23	—	0.54
348′	702′	33.3	38.7	17.6	4.8	—	5.4	0.5	1.0	0.16	—	0.38
337′	713′	37.1	35.8	20.0	3.8	—	3.1	0.5	1.0	0.27	—	0.38
324′	726′	34.0	40.3	20.9	—	—	4.7	0.4	1.0	0.21	—	0.38
313′	737′	28.8	40.5	23.2	3.7	—	3.8	0.5	1.0	0.19	0.21	0.38
297′	753′	24.2	41.6	28.8	2.2	—	3.2	0.6	1.0	0.15	—	0.32
285′	765′	38.2	29.5	22.8	3.5	—	5.6	0.6	1.0	0.14	—	0.32
273′	777′	28.9	46.6	20.3	0.8	—	3.3	0.3	—	0.13	—	0.27
266′	784′	27.9	48.4	19.6	1.7	—	2.5	0.2	0.7	0.13	—	0.20
250′	800′	41.6	43.8	10.7	0.5	—	3.4	0.3	1.0	0.13	—	0.27
186′	864′	28.6	55.4	13.4	1.0	—	1.4	0.3	0.4	0.11	0.18	0.70
154′	896′	39.6	40.2	16.5	1.8	—	2.0	0.4	0.5	0.09	—	0.54
103′	947′	19.6	65.1	12.5	0.4	—	2.3	0.2	0.5	0.09	—	0.27
101′	949′	22.3	57.0	17.6	—	—	2.7	0.2	—	0.07	—	0.23
91′	959′	40.8	43.4	12.2	0.7	—	2.8	0.2	0.3	0.07	—	0.14
50′	1000′	30.0	53.3	10.5	2.5	—	3.6	0.3	1.0	0.07	—	0.27

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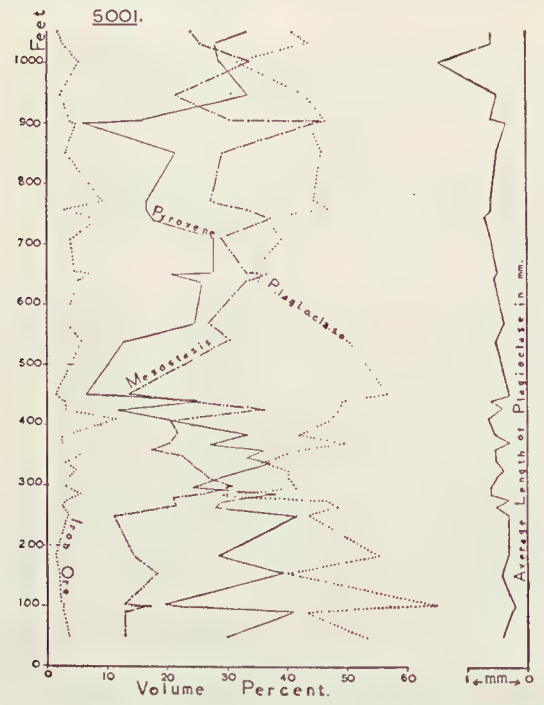

FIG. 6.—Plot of micrometric analyses of Bore Core 5001, Tasmania.

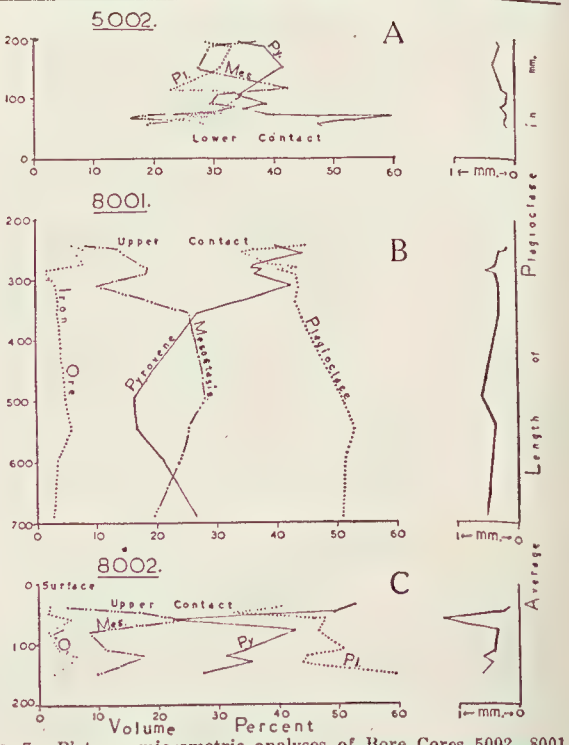

FIG. 7.—Plots o mic ometric analyses of Bore Cores 5002, 8001 and 8002, Tasmania.

TABLE III

Bore Core 5002

Height above base of bore	Depth from surface	Pyroxene	Plagioclase	Mesostasis	Average length of Plagioclase	Predominating width of Plagioclase
138′	8′	34.2	28.7	37.1	0.30	0.07
133′	13′	38.6	33.0	28.4	0.24	0.08
97′	49′	41.3	31.1	27.6	0.30	0.08
59′	87′	35.2	22.6	42.2	0.24	0.08
54′	92′	34.3	34.9	30.8	0.30	0.08
37′	109′	38.2	32.3	29.5	0.32	0.08
30′	116′	34.9	31.5	33.6	0.25	0.08
22′	124′	38.7	31.2	30.0	0.25	0.07
17′	129′	47.5	25.7	26.8	0.20	0.05
15′	131′	59.2	23.5	17.2	0.18	0.04
14′	132′	54.9	28.9	16.2	0.18	0.05
11′	135′	53.5	23.4	23.0	0.18	0.04
9′	137′	50.1	26.9	23.0	0.20	0.04
5′	141′	47.2	33.2	19.2	0.20	0.05
2′	144′	47.9	33.4	18.7	0.28	0.06

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The Bore 5002 penetrates about 150 feet of dolerite and exposes the base of the sill. The modal analyses are plotted in fig. 7 *a* where it is seen that pyroxene and plagioclase are of similar amount, with the former in excess at the contact. Unfortunately iron ores have been counted with the mesostasis, so that the only reliable comparison that can be made with the other diagrams is on the basis of the pyroxene and plagioclase curves.

Figure 7 *b* shows an upper contact and a comparison with the standard pattern indicates that here the marginal zone is about 70 feet in width, since both pyroxene and plagioclase are very close together in amount, below this there is a sudden increase in the amount of plagioclase and of mesostasis and a concomitant decrease in pyroxene. To the present writer such a pattern indicates a sill of thickness comparable to the Palisade, Mount Wellington and 5001. Figure 7 *c* also shows an upper contact, the marginal zone being about 50 feet in thickness. This, together with the marked deviation of the curves for plagioclase and pyroxene below this level, also suggests a sill of somewhat similar dimensions.

TABLE IV

Bore Core 8001

Depth from upper contact	Depth from surface	Pyroxene	Plagioclase	Mesostasis	Chlorite	Quartz	Iron Ores	Averag length of Plagioclase	Predominating width of Plagioclase		
1′	245′	39.9	45.1	—	6.9	1.9	6.2	0.20	0.01	—	0.04
6′	250′	42.2	36.0	10.3	3.4	—	8.0	0.20	0.20	0.04	0.09
11′	255′	44.7	34.2	12.4	2.1	—	6.6	0.30	0.03	0.05	0.12
30′	274′	36.3	38.8	14.6	3.1	—	8.1	0.36	0.04	0.11	0.16
36′	280′	36.0	43.5	13.7	4.4	0.2	4.4	0.42	0.05	—	0.20
41′	285′	37.6	40.3	16.0	1.8	0.8	1.8	0.49	0.13	—	0.45
46′	290′	36.4	43.3	17.5	0.3	0.5	1.9	0.36	0.07	—	0.27
66′	310′	42.5	43.5	9.4	1.0	—	3.4	0.29	0.05	0.12	0.22
91′	335′	34.2	43.3	16.7	1.9	0.2	3.6	0.30	0.05	—	0.15
110′	354′	26.8	44.1	22.9	2.5	0.1	3.4	0.29	0.03	—	0.13
200′	444′	19.8	48.3	22.4	4.1	0.9	4.3	0.48	0.09	—	0.23
250′	494′	16.5	50.9	23.5	4.6	—	4.5	0.59	0.06	0.18	0.38
300′	544′	16.7	52.3	21.9	3.4	—	5.6	0.36	0.07	—	0.13
350′	594′	21.0	51.6	17.6	6.5	—	3.3	0.42	0.07	0.13	0.23
446′	690′	26.3	51.1	16.1	3.7	—	2.7	0.50	0.13	—	0.30

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TABLE V

Bore Core 8002

Depth from upper contact	Depth from surface	Pyroxene	Plagioclase	Mesostasis	Chlorite	Quartz	Orthoclase	Iron Ores	Average length of Plagioclase	Predominating width of Plagioclase		
5′	37′	52.7	40.3	4.5	0.4	—	—	2.0	0.15	0.04	—	0.0
16′	48′	49.1	32.3	14.4	2.4	—	—	1.9	0.30	0.07	0.10	0.30
29′	61′	22.9	47.6	16.2	4.6	3.3	—	5.2	1.25	0.36	—	0.72
49′	81′	42.4	46.9	3.5	3.3	2.0	—	1.8	0.35	0.09	0.13	0.21
79′	111′	34.6	50.7	6.1	3.8	1.4	—	3.3	0.40	0.13	—	0.21
89′	121′	31.3	44.6	14.0	2.0	1.5	—	6.3	0.60	0.14	0.18	0.39
99′	131′	35.4	44.1	5.0	7.0	2.8	—	5.3	0.45	0.13	—	0.45
117′	149′	27.3*a*	59.2	5.7	1.7	2.5	0.9	2.6	0.60	0.11	0.16	0.36

a Little Hornblende counted as Pyroxene.

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GRAIN SIZE

Walker (1940) quotes the average length of plagioclase at different levels in the Palisade sill and these are plotted in figs. 1-4. To make the comparison of the Tasmanian sills with the New Jersey intrusion as complete as possible the length of plagioclase crystals were also measured in all slices from which a micrometric measurement was made and these are plotted in figs. 5, 6 and 7.

The Palisade examples all show that the crystals are shorter at the lower contact and steadily increase in length to about the 50 foot level and then rapidly attain a maximum in the olivine ledge, above which there is a sharp fall and then a steady slow rise to within about 100 feet of the upper contact above which a marked diminution in length is apparent.

Many of the Tasmanian rocks contain plagioclase crystals of two predominating lengths as shown in tables I-IV, but there is usually some gradation in size and an average is plotted in most cases, though in a few instances the predominant size has been taken. A comparison of the lengths plotted in figs. 5, 6 and 7 with those in figs. 1-4 will show a general similarity and the many small variations indicate possible veins and schlieren as noted above.

In figure 8 curves representing the frequency of distribution of plagioclase crystals of varying width are plotted for rocks at 18 feet and at 102 feet above the base of the Mount Wellington sill. The widths of 400 separate plagioclase crystals were measured in each slide by following parallel lines across the slide and measuring every crystal on the line. In the case of the 18 foot level it will be seen that there is a marked peak at 0·04 mm. and a smaller one at 0·18 mm. The curve for the rock at 102 feet shows a peak at 0·05 mm. and a minor one at 0·20 mm. The larger crystals are prominent but less abundant, but as they are often tabular there is a spread in the widths and their frequency is probably greater than is apparent.

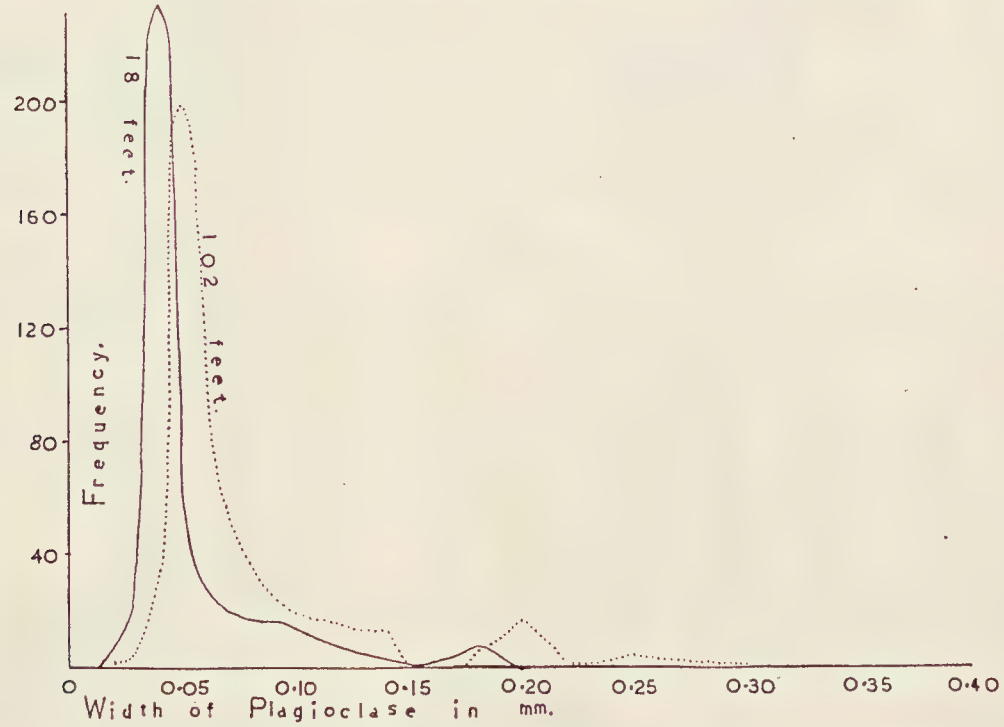

FIG. 8.—Plots of frequency distribution of widths of plagioclase crystals at 18 feet and 102 feet, Mt. Wellington.

In other slides measurements were made on a far smaller number of crystals, so the measurements listed in tables 1-5 and plotted in fig. 9 cannot be taken as absolutely accurate, though they are regarded as fair approximations. In some rocks three distinct widths of crystal are apparent and such are listed in the tables. In fig. 9, however, only the most frequent smaller crystal widths are plotted since it is believed that these grew *in situ* and may therefore be plotted in relation to depth, whereas the thicker ones possibly cooled in a different environment and may have come from a different level. Reference to fig. 9 *a* shows a steady increase in width from the lower contact to the top of the section, with a possible pegmatitic facies at about 1100 feet in the Mount Wellington sill. The adjacent fig. 9 *b* shows a very similar form indicating again that 5001 is behaving like a sill from which the upper contact has been removed and the lower not yet exposed.

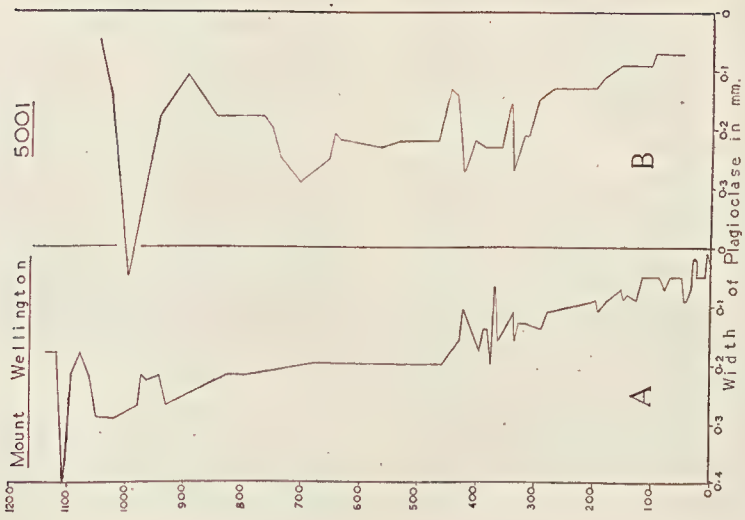

FIG. 9.—Plot to show width of smaller plagioclase crystals in relation to depth in the Mount Wellington sill and Bore Core 5001.

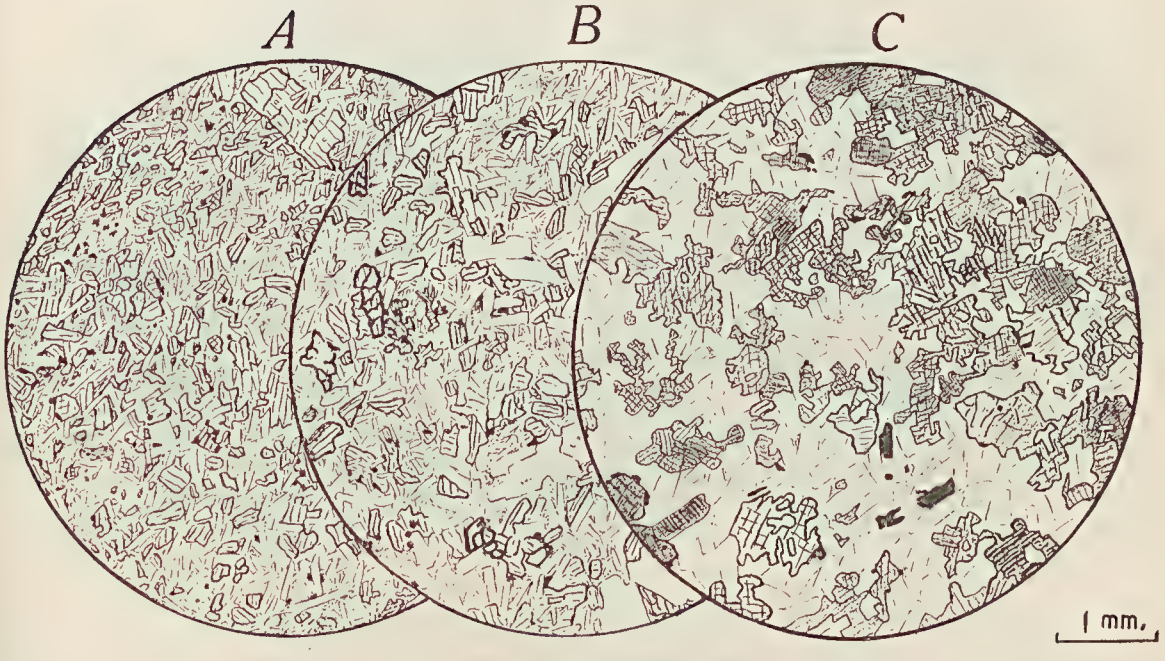

FIG. 10.—Mount Wellington. X 13

A. At contact. Fine-grained dolerite showing phenocryst of enstatite slightly moulded around small felspar laths. The remainder of the rock is intergranular, intersertal and slightly subophitic.

B. At 12 feet above basal contact. Phenocrysts of plagioclase and of partly resorbed orthopyroxene in an interstitial, intergranular and subophitic groundmass.

C. At 280 feet above basal contact. Ophitic dolerite, slightly intersertal. Note independent crystals of orthopyroxene (bottom left) and one partly moulded by clinopyroxene (middle right), also interstitial iron ore.

Winkler (1949) used the size of crystals in his discussion on the cooling of a basaltic magma, but his observations were made on rocks close to the margin and in this case it is hardly applicable when differentiation and accumulation of deuteric solutions have played so important a role.

FABRIC

So far as the present writer is aware the matter of differentiation has not been approached by a consideration of fabric. Yet it is significant, since an understanding of fabric leads to an understanding of order of crystallization and this in turn to an interpretation of the cooling history.

Most of the writers who discuss the quartz dolerites have mentioned that the marginal and fine grained varieties have an intergranular fabric whilst the coarser types are characterized by the ophitic and intersertal, but there appears to be no discussion as to the distance from the margin where this change of fabric takes place, how gradually it takes place, nor are there any observations on peculiarities of texture apart from the common development of phenocrysts.

At its lower contact the Mount Wellington dolerite is mainly intergranular and intersertal, but an occasional moulding of pyroxene on plagioclase suggests the subophitic fabric. Enstatite phenocrysts occur at this level and reference to fig. 10 *a* shows one of these moulded on small laths of felspar, thus suggesting that it grew rapidly *in situ* at the chilled margin, rather than that it represents an intratelluric crystal. It might be argued, however, that they were emplaced as embryo crystals and grew larger in their present position.

At 12 feet above the contact small phenocrysts of both plagioclase and enstatite occur. The enstatite shows resorption (fig. 10 *b*) and the fabric of the rock is partly intergranular, partly subophitic and markedly intersertal, and porphyritic. Professor Jaeger* has shown that at 12 feet from the contact the magma could be expected to take

* Personal communication. With reasonable values of the thermal properties of the magma the time for complete solidification is about four years if the magma is intruded at 1100°C and its range of solidification is 1100-800°C, and about two years if the magma is intruded at 1000°C, and the range is 1000-800°C.

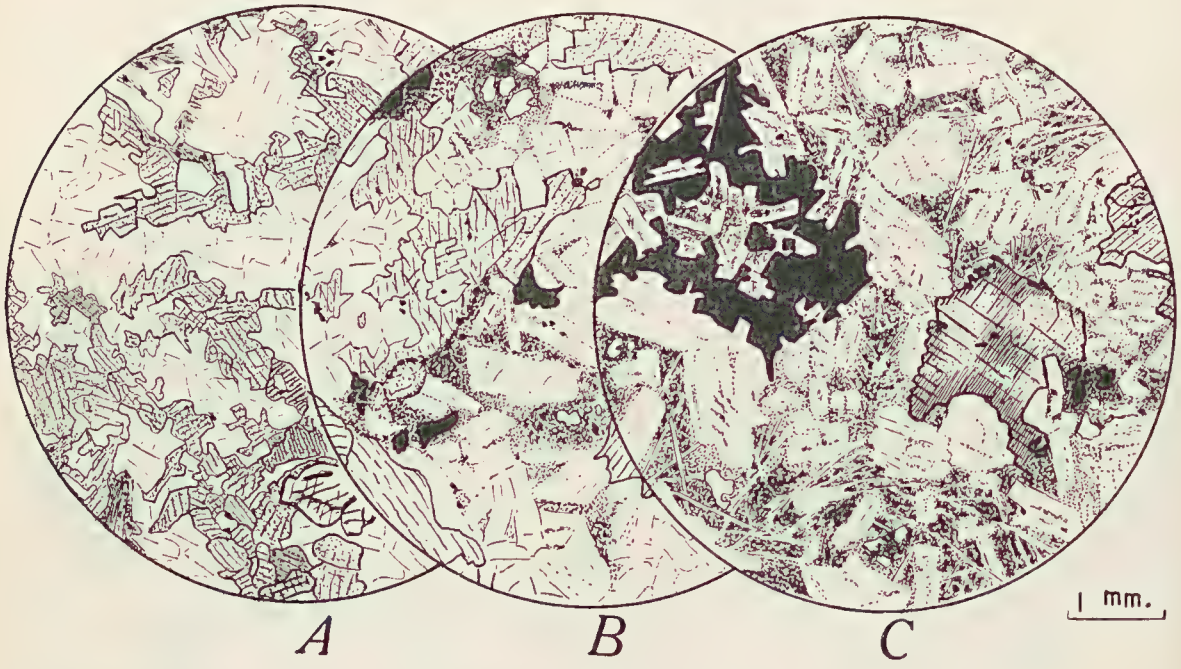

FIG. 11.—Mount Wellington. X 13.

A. At 335 feet above basal contact. Ophitic dolerite, intersertal in places. Note (bottom right), orthopyroxene partly resorbed and moulded by clinopyroxene, and (top) large zoned tabular felspar moulding felspar laths and pyroxene and idiomorphic against felspathic mesostasis.

B. At 945 feet above basal contact. Coarse ophitic dolerite highly intersertal. Note granules of iron ore bordering pyroxene around interstice, also group of smaller felspar laths (bottom, right).

C. At 1045 feet above basal contact. Coarse intersertal dolerite. Note iron ore moulded around felspar (the two smaller grains in the middle of the large grain are pyrite) also felspathic mesostasis containing patches of dark chlorite and long needles of plagioclase some of which are outgrowths from felspar laths. The pyroxene shows schiller inclusions of iron ore.

several years to consolidate, thus leaving ample time for a partial resorption of either intratelluric enstatite or of crystals that had cooled quickly near the contact and later disturbed by currents and brought up to a slightly higher level. The larger felspar crystals and the small patches of pyroxene moulded on felspar needles also suggest a disturbance of environment.

At 280 feet the fabric is fairly definitely ophitic (fig. 10 *c*) to subophitic and it is at this level that Edwards finds an enrichment of magnesia. At this level the pyroxene consists of both hypersthene and augite, and it is difficult to envisage a sinking of earlier-formed magnesia-rich pyroxene crystals when they mould the plagioclase. If the pyroxene were zoned it could be argued that additional growth took place in their present position, for the fabric certainly suggests growth *in situ*; zoning, however, is not apparent.

At 335 feet, and thereabouts, remnants of hypersthene are moulded by clinopyroxene, there is a well-marked ophitic and intersertal fabric and two generations of plagioclase occur, the larger felspars being slightly zoned and forming subidiomorphic tabular crystals which mould felspar laths and pyroxenes and themselves show idiomorphic relations towards the felspathic mesostasis (fig. 11 *a*).

Reference to table 1 shows that many of the larger felspars between 290 and 430 feet are zoned and fig. 8 indicates that the smaller felspars show much variation in size in this part of the section.

Towards the upper part of the sill the mesostasis plays a very important role and is commonly rich in iron ores and dark chlorite. The relation between pyroxene and plagioclase is ophitic and the rocks are highly intersertal (fig. 11 *b* and *c*).

Most of these fabrics and peculiarities of crystallization can be matched in 5001 though the intergranular fabric is present only in a few finer types that may represent veins, or inclusions of the marginal facies. The intersertal and the ophitic fabrics are persistant throughout (figs. 12 and 13), the former becoming more prominent at higher levels as in the case of the Mount Wellington sill.

Bore 5002 is intergranular for a short distance above the base, but rapidly becomes intersertal and ophitic.

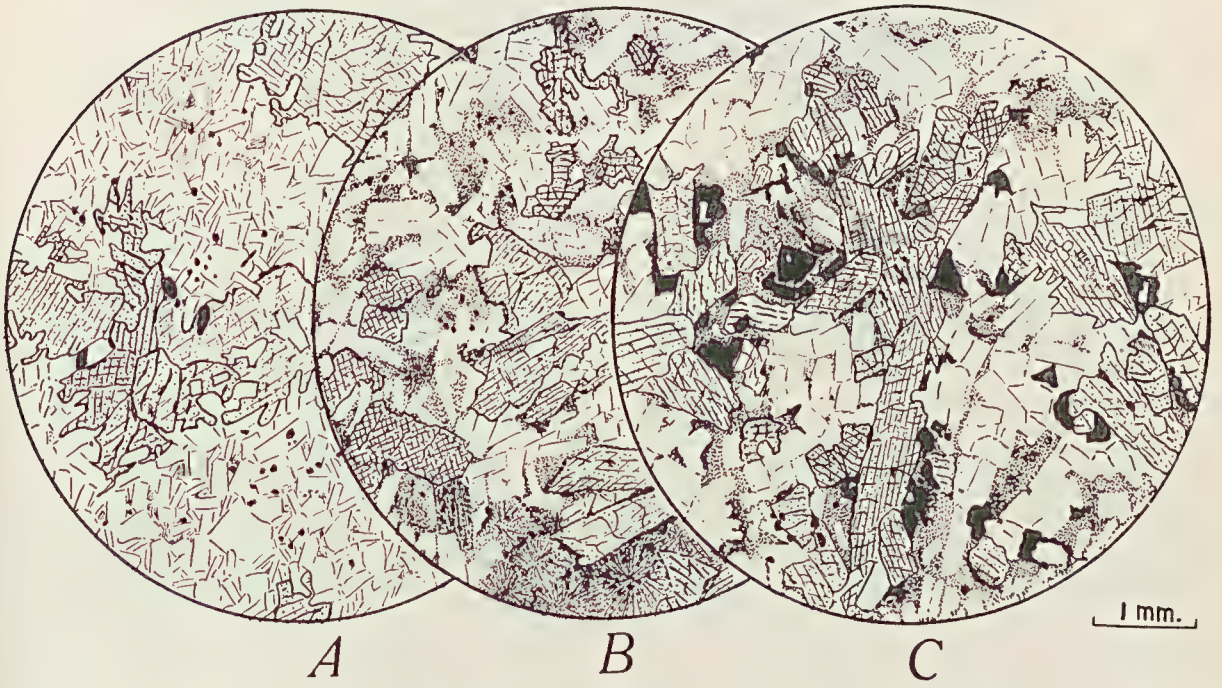

FIG. 12.—Bore Core 5001. X 13.

A. At 50 feet above base of bore. Ophitic dolerite partly intersertal, showing stout laths and small tabular crystals of plagioclase and large irregular grains of pyroxene.

B. At 285 feet above the base of bore. Ophitic dolerite highly intersertal showing subidiomorphic to idiomorphic columnar crystals of pyroxene. and mesostasis with radiating felspar.

C. At 410 feet above base of bore. Narrow mafic vein through optic dolerite. Elongated columnar crystals of pyroxene are approximately parallel to the length of the vein and adjacent felspar shows similar slight parallelism. The vein merges gradually into the ophitic dolerite and there is no sharp contact. Iron ore is interstitial.

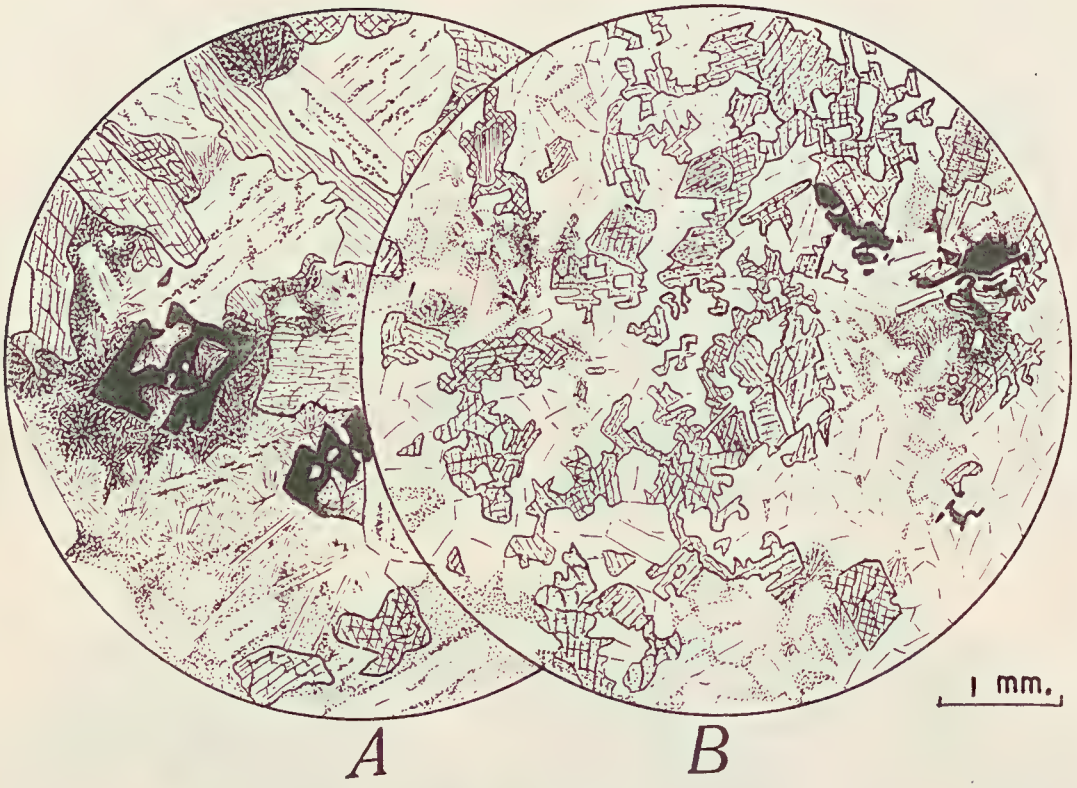

FIG. 13.—Bore Core 5001. X 16.

A. At 1000 feet above the base of bore. Pegmatite showing long columnar pyroxenes and large tabular felspars with much mesostasis. Note clusters of radiating felspar, dark chlorite and skeleton crystals of iron ore in the mesostasis.

B. At 1049 feet above base of bore. Ophitic dolerite, intersertal in places. Clinopyroxene moulded on pigeonite. Note decrease in grain size.

Bore 8001 shows an upper contact, and the rock against the tuffaceous sandstone contact is so fine grained that no micrometric analysis was attempted. The minute felspars appear to be plagioclase and tend to form radiating groups. The fabric is porphyritic, intergranular and intersertal, the minute grains of iron ore being confined to the intersticies (see fig. 14 *a*). A little xenocrystal quartz occurs. The phenocrysts are completely altered into bright green iddingsite, and their form in most cases suggests original pyroxene, though one or two sections resemble the form of olivine and it is possible that both minerals may have occurred. One foot below this type the rock resembles a normal fine-grained dolerite, though there is still a slight tendency towards a radial grouping of the plagioclase (fig. 14 *b*). Quartz is prominent in the intersticies throughout the marginal zone and is probably due to contamination with the overlying sandstone.

NOTES ON DIFFERENTIATION

The difficulties regarding the acceptance of crystal settling by gravity have been discussed by Jaeger and Joplin (1955, 1956) and in his discussion on the latter paper Hess (1956) concludes that this mechanism does not occur to any appreciable extent in the differentiation of the quartz dolerites as they are typically unlaminated. Many of the points noted above add to this difficulty, but they also present difficulties regarding the sinking of large blocks as postulated by Jaeger and Joplin.

Until further data is available it is not proposed to enter into a full discussion on differentiation, but at this stage it might be pointed out that the sinking and *shattering* of blocks with an accompanying disturbance of the bottom "sediment" may account for many of the observed phenomena.

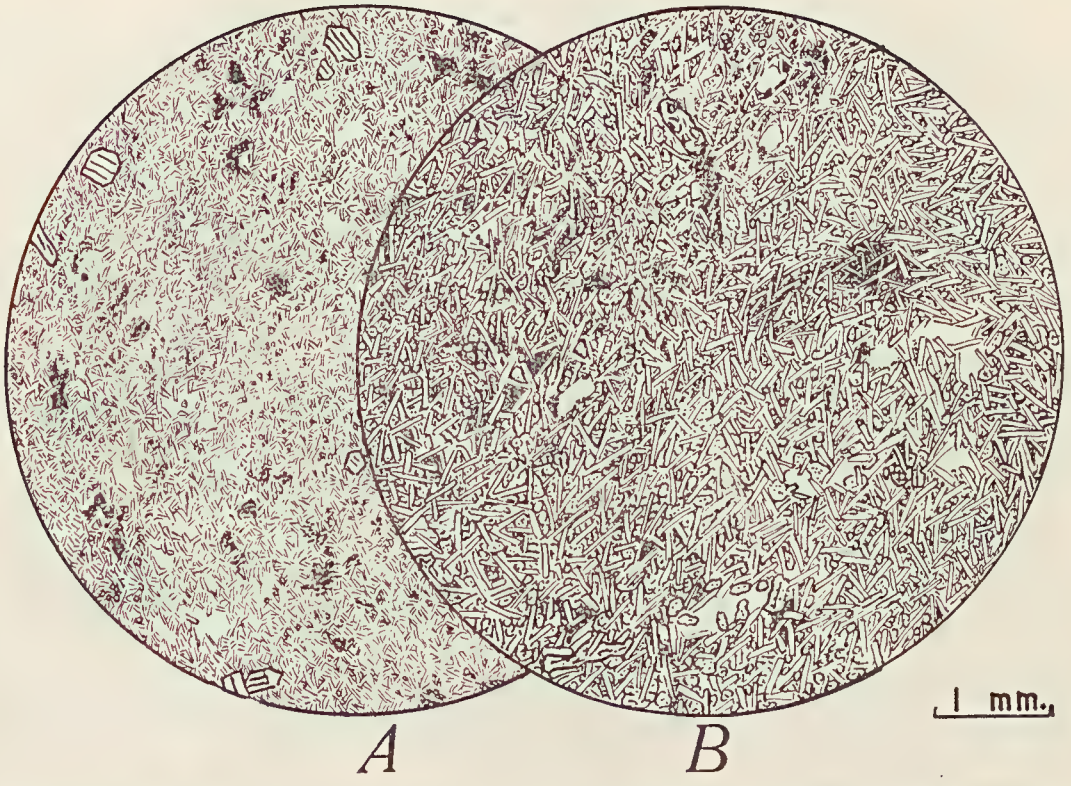

FIG. 14.—Bore Core 8001. X 16.

A. At contact. Extremely fine basaltic phase showing pseudomorphs of iddingsite, after hypersthene or (?) olivine in a base of felspar and intergranular pyroxene.

B. At 5 feet below contact. Fine intergranular phase showing small altered microphenocrysts of enstatite, few microphenocrysts of plagioclase and numerous small areas of quartz. Iron Ore is present in minute grains forming patches in the mesostasis.

If the falling blocks were not completely solid but consisted of a crystal mush and interstitial liquid, they would tend to fragment on their way to the bottom and might be accompanied by a shower of small fragments which may or may not reach the floor. As the larger fragments reached this floor, which would be strewn with only partly consolidated material, further breaking up might occur and turbidity current set up. Some of the felspar might tend to rise, and in the new environment become zoned, felspars of different size would become mixed either as individual crystals or as little clots of similar sized crystals giving rise to fabrics that have been observed in the lower part of the Mount Wellington sill.

As noted above the ophitic fabric in the magnesia-rich layer of Mount Wellington suggests crystallization *in situ*, yet it is known that magnesian pyroxene crystallized before iron-rich varieties and it has thus been assumed that this rock represents a gravity accumulation of early-formed crystals. Unfortunately exposures on the mountain are not good enough for this rock-type to be traced any distance horizontally, but if it is of local occurrence, which it might well be, then it seems not impossible that this was a fairly large block, which formed at an early stage near the roof and fell to its present position without much disintegration since its fabric is only slightly interstitial and the felspar and pyroxene are closely welded.

In general, however, the field evidence and above observations do not favour the final preservation of large settled blocks, but rather suggests that much of the early material started to drop as large units that shattered into a shower of crystals or minute fragments when they reached the floor, where they continued to grow or were enclosed by more rapidly cooling magma from which crystals of smaller grain size were separating.

As noted above, the chief point of difference between the Palisade sill and the Tasmanian sills is the presence of abundant olivine in the former. Accumulation of crystals seems to be the only means of accounting for the olivine ledge and Walker (1940, 1956) considers these were of intratelluric origin and that there was no hotter magma for them to melt in at the time of their settling. The presence of the olivine ledge therefore indicates that the magma was supercooled at the time of injection. Recently Jaeger and Joplin (1956) have discussed Walker's comments and have pointed out

that certain magmas are not supercooled at the time of injection and that small phenocrysts may develop at the margin owing to sudden cooling. The fact that there is no accumulation of enstatite crystals to form a ledge in any of the Tasmanian sills, seems to support this view. Thus, apart from the slightly more basic composition of the initial magma in the case of the Palisade sill, the main point of difference between it and the Tasmanian sills is that the first was intruded in a super-cooled state and contained suspended crystals and that the Tasmanian magma was not super-cooled at the time of injection.

CONCLUSION

Reference to the appendix will show that the densities plotted in figs. A (*a*, *b* and *c*) are consistent with plots of modal composition, thus the peak at about 300 feet in fig. A (*a*) is the point suggested by fig. 5 as the place where the true deviation of plagioclase and pyroxene really occurs. Furthermore, a comparison of figs. A (*a*) and A(*b*) suggests, as does figs. 5 and 6, that the base of 5001 is possibly about 250 to 300 feet below the present level of the bore and that the Mount Wellington sill has been denuded to a level slightly below that of 5001. The same observations can be made with regard to the magnetic susceptibilities in figs. 9 B (*a* and *b*).

Apart from their possible use as a means of interpreting magmatic differentiation, it seems to the present writer that these data may have an economic application in predicting the approximate thickness of a sill. As many of the drill holes put down by the Hydro-Electric Commission pass through these sills, it would probably be of value to know what thickness of dolerite might be expected in the bore and whether the present level of boring is near the top or the bottom of the sill. The study of fabric and grain size and a series of micrometric measurement should give a fair approximation and although the method is not conclusive, the detailed study of a number of sills may help to make it a more reliable tool.

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AUTHOR'S NOTE.—Since the completion of this manuscript, a paper by J. F. Truswell (*Trans. Roy. Soc. S. Africa*, 1955, 34, 409-416) has come to the writer's notice. Modal analyses of Karoo dolerite in an 820 foot sill are plotted, and the diagram is very similar to figs. 1-7 of the present paper. Variations in modal composition, and the presence of veins near the base of the sill, are accounted for by a later injection of undifferentiated magma. This explanation was considered in the case of some Tasmanian sheets.

APPENDIX

THE VARIATION OF DENSITY AND MAGNETIC PROPERTIES

In Jaeger and Joplin (1955) the general variation of magnetic susceptibility and intensity of magnetisation in the sill 5001 were discussed in detail and were compared with observations of the density and petrography. These were found to form a pattern consistent with differentiation in the sill. This pattern is followed in the additional sills now examined by Dr. Joplin and may be taken as the characteristic behaviour of sills of this type. Only the average values of density and magnetic properties will be reported here: as remarked in Jaeger and Joplin (1955), the latter, in particular, show a fine structure which is believed to be significant, but this will not be discussed.

The Density

In figure A (*a*) the variation of density in Mt. Wellington is shown. Each value is the average of all samples in a 50 foot interval; 20 or more samples have been taken in each of the lower intervals, but only two or three in each of the upper ones, so that the values given for the upper part of the sill may differ considerably from the true mean value which may be regarded as following the dotted curve. The density is seen to increase slowly to a maximum at about 300 feet from the lower contact, followed by a rapid decrease around 400 feet—this is the point at which the rapid falling off in the volume percentage of pyroxene appears in fig. 5.

The behaviour of the density in 5001, taken from Jaeger and Joplin (1955), is shown in fig. A (*b*) and is seen to be very similar to that of Mt. Wellington. Combining the two, it may be suggested that the typical variation of density in a thick sill of magma of this type consists of a rapid fall in density setting in 50 or 100 feet below the upper margin, the density having its minimum value some hundreds of feet below; there is then a rise to a maximum some hundreds of feet above the lower contact, with a subsequent slight decrease towards the lower contact. The behaviour of the other three incomplete cores examined fits into this pattern. In 5002, the density increases from 2·90 near the lower contact to 2·93 over the remaining 120 feet (this relatively uniform density would also be shown if the sill were a thin one). The sill 8002 has an average density of 2·90 with little fluctuation in the first 100 feet below the upper contact; below this there is a considerable fall in density as well as great fluctuations in it, values between 2·67 and 2·80 having been measured. The sill 8002 shows similar behaviour, in this case the density is relatively constant at 2·90 for only 20 feet from the upper contact after which a rapid fall takes place, values between 2·62 and 2·81 having been measured.

The behaviour of the Palisade sill (George Washington Bridge and Edgewater sections), fig. A (*c*), is very different, the change being attributable to the olivine layer and to the presence of olivine near the upper margin. In the regions in which olivine is not present, the curve of fig. A (*c*) is not very different to figs. A (*a*) and A (*b*); this lends some support to the suggestion of Jaeger and Joplin (1956) that the olivine ledge is formed by a fall-out of intra-telluric olivine crystals, subsequent differentiation having followed very much the pattern of the sills described in this paper.

Magnetic Properties

Susceptibilities have been measured by the method described in Jaeger and Joplin (1955). The reversible susceptibility of a number of samples from Mt. Wellington has also been measured accurately by Mr. D. W. Smellie in an apparatus similar to that of Bruckshaw and Robertson* (1948), using a peak field of 0·25 oersted at 50 cycles. Values obtained in this way are consistently about 10 per cent higher than those measured by the simple apparatus described in Jaeger and Joplin (1955) which is thus shown to be completely adequate for comparative work of the present type.

Values of the average susceptibility of samples taken in 50 feet regions from Mt. Wellington are shown in fig. B (*a*), and those for 5001 in fig. B (*b*) for comparison. Mt. Wellington shows a rapid fall from the marginal values to a very low value 200 feet above the lower contact, followed by a steady rise. Comparison with fig. B (*b*) suggests that this minimum may be below the lowest level measured in 5001; also, it may be expected that, as the upper contact of Mt. Wellington is approached, the susceptibility would fall towards a marginal value. Of the two upper contacts measured, 8001 shows relatively constant values for 100 feet from the margin, followed by an increase, while 8002 shows constant values for 40 feet followed by an increase: both these results show variations consistent with those of the density and petrography. 5002, however, is to some extent anomalous, values in the regions 20-80 feet being lower than the value at the contact.

* Bruckshaw, J. McG., and Robertson, E. I., *J. Sci. Inst.*, Vol. 25, p. 444.

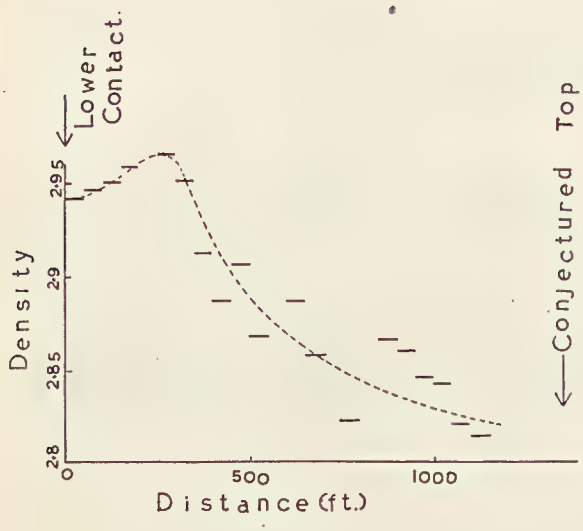

Fig. A (a)

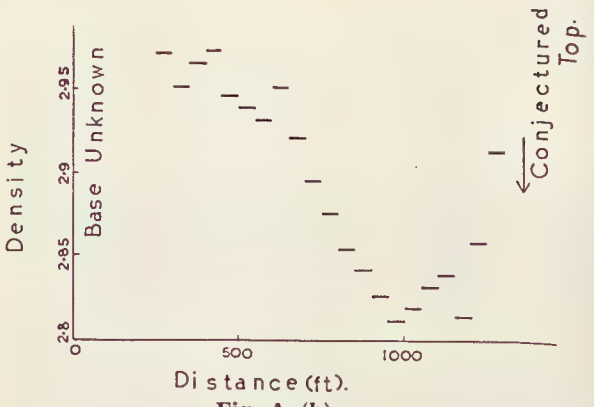

Fig. A (b)

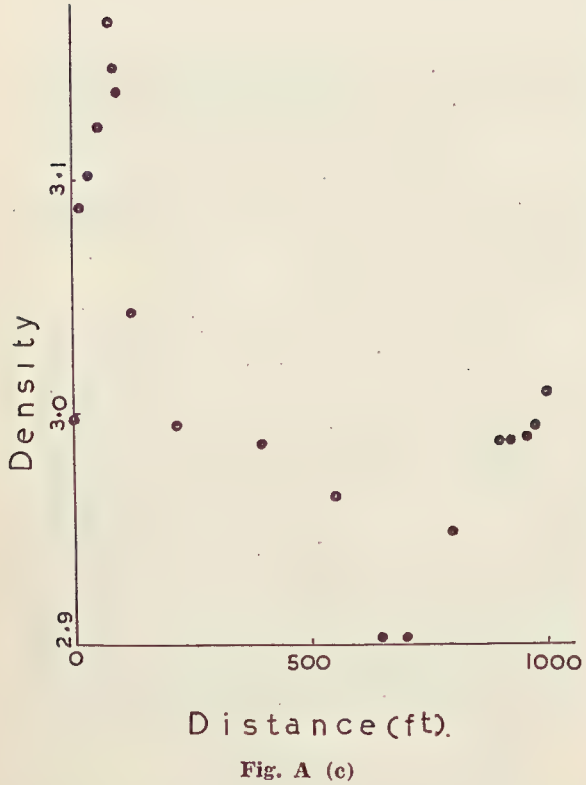

Fig. A (c)

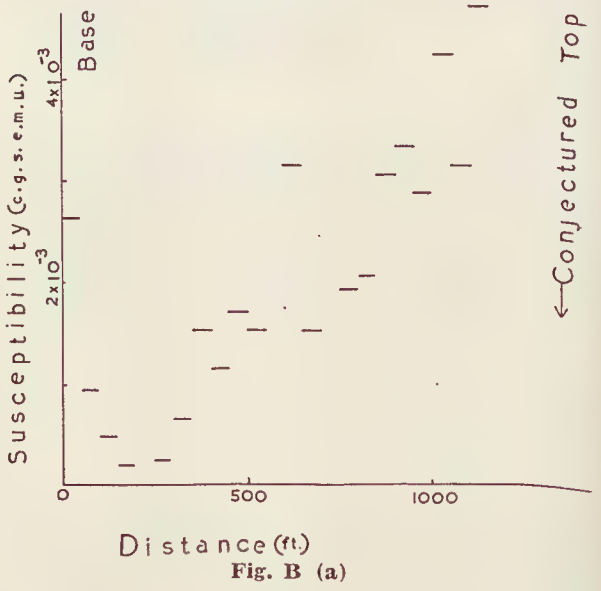

Fig. B (a)

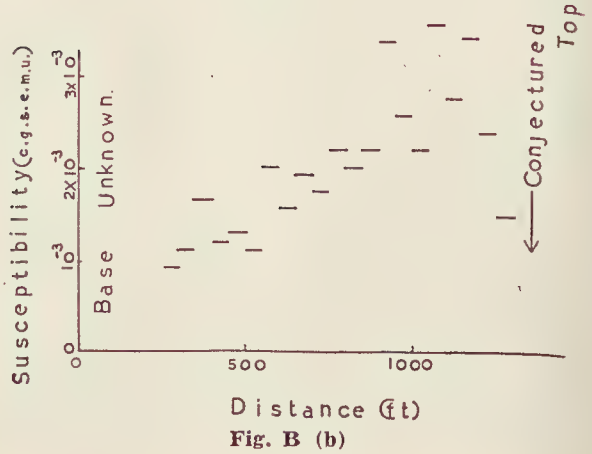

Fig. B (b)

OBSERVATIONS ON SOME TASMANIAN FISHES: PART VIII

By

E. O. G. Scott

ABSTRACT

A description is given of the inadequately-known stingray, *Dasyatis brevicaudatus* (Hutton, 1875) [Dasyatidae: Tasmanian representatives keyed], the large female dealt with apparently providing the first formal record of this species from Tasmania. A sample of six specimens of *Muraenichthys breviceps* Günther, 1876 [Echelidae], with a good approximation to a normal distribution of standard length, affords evidence of linear regression of some smaller anatomical features on major body regions. Observations are made on occurrence, nuptial coloration, standard length-total length ratio, and postmortem mouth posture in *Atherina microstoma* Günther, 1861 [Atherinidae]. Ontogenetic features of pigmentation and fin-membrane formation shown by a juvenile *Bovichtus variegatus* Richardson, 1846 [Bovichtidae] are noted. Form and size in the spines of the javelin fish, *Allomycterus pilatus* Whitley, 1931 [Diodontidae: Tasmanian representatives keyed], are briefly analysed.

In this as in some earlier contributions the word *Fishes* is interpreted *sensu lato* to include Elasmobranchs: the series of keys to the Tasmanian members of the families represented by species discussed is continued. Tables of synonomy are set out in general accordance with the well-considered suggestions of Schenk & McMasters (1948); while the selection of data for record in the quantitative specification of populations follows the recommendations of Simpson & Roe (1939). All linear dimensions are recorded in millimetres; except where its absence might lead to confusion, the name of the unit is omitted. Standard length and total length are regularly denoted by the symbols *LS*, *LT*, respectively.

Family DASYATIDAE

Australian genera and species enumerated in the Check List (McCulloch, 1929) total 7 and 17: Whitley (1940) recognizes the same number of species (two dropped, two described since 1929) but places them in 9 genera. Both authorities list three species for Tasmania: *Urolophus cruciatus* (Lacépède, 1804)—the synonymic *U. ephippiatus* Richardson, 1845, has Storm Bay, Tasmania as type locality—, *U. bucculentus* Macleay, 1884, *U. viridis* McCulloch, 1916. Earlier McCulloch (1921 *b* : 465) stated he had seen both *Dasyatis brevicaudatus* (Hutton, 1875) and *D. thetidis* Waite, 1899 trawled off the eastern coast of Tasmania; but he apparently either overlooked this record or was not satisfied with his determinations when he came to compile the Check List, in which localities for the former species are restricted to Bass Strait, New South Wales, South Australia, New Zealand, and for the latter to New South Wales: Whitley (1940) gives the same distributions. A specimen of *Dasyatis brevicaudatus* described below appears to furnish the first satisfactory record of the species from this State. (*See* Addendum, p. 156.)

D. thetidis has recently been recognized (partly on a record dating back to 1881) in New Zealand (Richardson and Garrick, 1953); and I have added it, for reference should occasion arise, to the subjoined key to the local members of the family.

Key to Dasyatidae Recorded from Tasmania [plus *Dasyatis thetidis* Waite]

A. Caudal fin present. Dorsal fin present or absent. No ventral caudal keel. Disc-width < 2 ft. (modally 15-20 in.).

B. Length of tail $<$ its distance from mouth. Dark cross-like markings on back .... *Urolophus cruciatus*

BB. Length of tail $>$ its distance from mouth. No dark cross-like markings on back.

C. Disc characteristically wider than long (without pelvics). Buccal papillae behind lower jaw more numerous (about 10, or more), their interspaces decidedly $<$ their length. Pale brownish above and below, with numerous small white spots and vermiculations .... *Urolophus bucculentus*

CC. Disc characteristically longer (without pelvics) than wide. Buccal papillae behind lower jaw less numerous (about 7, or fewer), their interspaces $\geq$ their length. Mainly light greenish above, whitish marginally; mainly white below, somewhat purplish marginally .... *Urolophus viridis*

AA. Caudal fin absent. Dorsal fin absent. A ventral caudal keel present. Disc-width > 2 ft. (to at least 5 ft.).

D. Length of tail $\leq$ length of disc. Spear extending over part of posterior half of tail. Ventral caudal keel not extending to tip of tail; its length < 2 (usually subequal to) length of spear. Upper disc smooth, or with several spine-bearing tubercles .... *Dasyatis brevicaudatus*

DD. Length of tail > (about 1·3-1·4) length of disc. Tip of spear not reaching nearly to mid-point of tail. Ventral caudal keel extending to tip of tail; its length > 2 (usually 4-5) length of spear. Upper disc largely smooth, but with spine-bearing tubercles tending to form one or more clearly defined longitudinal rows at, or near, middle of disc behind eyes .... *Dasyatis thetidis*

Genus **DASYATIS** Rafinesque, 1810

DASYATIS BREVICAUDATUS (Hutton, 1875)

Trygon brevicaudata Hutton, 1875, *Ann. Mag. Nat. Hist.*, (4), XVI: 317. Type locality: Dunedin, New Zealand.

[?] *Dasyatis brevicaudatus* (Hutton). Waite, 1909, *Rec. Cant. Mus.*, 1: 151, pl. XXII.

Dasyatis brevicaudatus (Hutton). McCulloch, 1915, Biol. Results Endeavour, III, I: 102, pl. XV, fig. 1, pl. XVII, fig. 1. McCulloch, 1921, *Proc. Linn. Soc. N.S.W.*, XLVI, (4): 426, text fig. 2. Waite, 1923, Fishes S. Aust.: 51, fig. Garrick, 1954, *Trans. Roy. Soc. N.Z.*, 82, 1: 189, text figs. 1, 2. McCulloch, *Mem. Aust. Mus. Sydney*, V, 1: 26.

[*non*] *Dasyatis brevicaudatus* (Hutton). Waite, 1921, *Rec. S. Aust. Mus.* II, I: 31, fig. 44.

[? *part.*] *Dasyatis brevicaudatus* (Hutton). Smith, 1950, Sea Fishes Southern Afr.: 70, fig. 81 (whole fish?; not jaws).

[?] *Trygon schreineri* Gilchrist, 1913, *Trans. Roy. Soc. S. Afr.*, III: 33. Type locality: False Bay, Agulhas Bank, South Africa.

[?] *Dasybatis schreineri* Gilchrist. Barnard, 1925, *Ann. S. Afr. Mus.*, 1: 76.

Bathytoshia brevicaudata (Hutton). Whitley, 1933, *Rec. Aust. Mus. Sydney*, XIX, 1: 61. Whitley, 1940, Fishes Aust., 1; 201, figs. 223, 227, 228, 230, 231.

[*non*] *Bathytoshia brevicaudata* (Hutton). Waite in Whitley, 1940, Fishes Aust., 1, fig. 232.

Material; general remarks.—The present observations were made, on 15th January, 1952, on a large female at East Beach, Ulverstone. One male and three female examples of the eagle ray, *Mylobatis australis* Macleay, 1881, were lying on the sand nearby. These five rays are probably the subject of the following note in *The Advocate* of 17th January: "A party netting" on the eastern side of Button's Creek, "several nights ago caught four stingrays in one haul, the largest measuring six feet long and five feet across. The spear of the largest was 15 inches long. Efforts to kill the ray resulted in a broken oar, and finally an axe was used. Others netted were smaller but nevertheless dangerous. The party netted another ray the same evening".

The recent survey made by Garrick (1954), in the course of his study of this species, of the published data makes very apparent the meagre and inconclusive nature of our present knowledge concerning it. It is evident we are—at any rate in respect of rays from Australian waters—still at the primitive stage of inquiry that calls less for the analysis and comparison of extant information than for the routine accumulation of raw systematic material in the shape of mere observational data. The following fairly detailed notes on the Ulverstone example should make some contribution to the immediate need.

Dimensions.—All measurements made are set out in Table I, grouped, for convenience of reference, under 12 sectional headings.

TABLE I

Dasyatis brevicaudatus (Hutton, 1875). Dimensions of a female from Ulverstone, 15th January, 1952. "Length to" = "length from tip of snout to"; b.p. = between parallels; f.c. = following curve of surface or boundary; d.m. = direct measurement, as with dividers; if no specification, measurement is to be understood to be b.p., if applicable, otherwise d.m. (The larger dimensions were originally recorded to nearest sixteenth of an inch, here converted to millimetres; smaller dimensions taken directly in millimetres.)

Dimension	mm
A. Disc:	
Length to level of posterior border, without pelvics	1156
Length to hindmost point on posterior border of disc: d.m.	1162
Tip of snout to angle (*i.e.*, length of anterior border): d.m.; f.c.	787; 819
Angle to hindmost point on posterior border of disc (*i.e.*, posterior border of pectoral): d.m.; f.c.	781: 797
Length to level of maximum width (*i.e.*, to level of angle)	495
Width at spine t_4 (*i.e.*, at 806 mm behind tip of snout)	1029
Width at dorsal origin of tail (*i.e.*, at 1070 behind tip of snout)	610
Maximum height; length to level of this measurement	260; 580

Dimension	mm
B. Pelvics:	
Length to level of posterior border	1264
Length to middle of interpelvic notch	1171
Spread of pelvics: as they lie; fins pulled taut	457; 500
Anterior outer insertion of pelvic to outermost point on its margin, d.m.; on dorsal surface; on ventral surface	165; 240
Anterior outer dorsal insertion of pelvic to inner end of posterior border: f.c.	419
Anterior outer ventral insertion of pelvic to most anterior point on vent: d.m.	75
Length of hind margin	210
C. Tail, vent, ventral cutaneous keel:	
Length to dorsal origin of tail	1070
Intact proximal tail segment *A*: length from its dorsal origin; from end of postanal gutter; from middle of vent proper	514, 590, 655
Partly severed tail segment *B*: length	238
Total length of tail as extant from middle of vent proper	893
Estimated length of complete tail	1010
Total length to: tip of tail as extant; tip of complete tail (estimated)	1822; 1939
Length to anterior margin of vent	894
Length of vent: without; with postanal gutter	70; 100
Maximum width of vent	25
Tail: width; depth; girth:	
Near dorsal origin	124; 77; —
At level of angle of pelvics	101; —; 270
At level of spine t_5 (i.e., at 1298 behind snout-tip)	90; 57; 245
At level of spine t_9 (i.e., at 1481 behind snout-tip)	60; 43; 176
At level of origin of spear (i.e., at 1530 behind snout-tip)	43; 40; 135
At level of termination of spear-groove (*i.e.*, at 1770 behind snout-tip; keel disregarded)	15; 21; —
Length to present origin of ventral cutaneous keel (imperfect anteriorly)	1584
Length of keel (imperfect anteriorly and posteriorly)	237
Height of keel: at present origin; present middle; present termination	10; 19; 12
D. Snout, eyes, spiracles:	
Subtriangular snout-tip (contour laterally lapses freely into fin-border, and limits of the projecting region must be determined more or less arbitrarily): base of triangle; height (anterolateral extent) of triangle	*ca* 30; *ca* 10
Interorbital distance	279
Interspiracular distance (minimum)	241
Length to level of front of spiracles	321
Length of spiracle: b.p.; d.m.	73; 79
Height of spiracular eminence	12
E. Mouth region:	
Length to middle of anterior border of: upper lip; lower lip	205; 231
Width of mouth	140
Length to level of front of internasal flap	145
Anterolateral tip of internasal flap to angle of mouth, d.m.	75
Internarial distance (to outer border of nostrils)	192
Visible dentigerous width of: upper jaw; lower jaw	110; 67
Nasal sac, d.m.: major axis; minor axis	75; 20
Teeth: length (anteroposterior); width	2·5-3; 4-4·5
F. Gill slits, G_1-G_5:	
Length to most advanced point of: G_1; G_2; G_3; G_4; G_5	360; 405; 450; 497; 538
Distance between successive slits of one side: at outer extremities of slits; at inner extremities:	
G_1-G_2	45; 45
G_2-G_3	45; 40
G_3-G_4	47; 40
G_4-G_5	41; 45

Dimension	mm
Oblique lengths of slits; distances, b.p., between inner extremities of right and left slits:	
G_1	45; 305
G_2	50; 293
G_3	55; 271
G_4	43; 246
G_5	31; 217
G. Large spinous tubercles or bucklers, t_1-t_{10}, on disc (t_1-t_4) and on dorsal surface of segment *A* of tail (t_5-t_{10}):	
Length to level of spinous tubercle; length of buckler; width of buckler; vertical height of whole structure; sloping height of boss or spine; direct length from tip of snout (t_3 only) or maximum width of spine (t_9 only):	
t_1	11; 3; 3·5; 1·8; —
t_2	21; 3·5; 5; 1·8; —
t_3	234; 3; 4; 1·5; —; 234
t_4	806; 16·5; 9·5; 8; 5;
t_5	1298; 16; 14; 8; 3
t_6	1355; 18; 11·5; 9; 3
t_7	1379; 15·5; 12; 5·5; 1·8
t_8	1419; 17·5; 10; 5; 10·8
t_9 (spine serrated)	1481; 27; 12; 14; 27; 4·5
t_{10}	1503; 16·5; 7; 7; 3
H. Spear and "spear groove":	
Length to origin of spear	(?) 1530
Spear: length, measured (imperfect), estimated; maximum width (near base)	62, 300+; 14
"Spear groove": Length to origin; approximate length	1530; 240
I. Selected spinous tubercles on ventral surface of tail:	
Length to spine:	
Sv_1—first ventral on right side	1424
Sv_2—first ventral on left side	1427
Sv_3—first mesial ventral	1479
J. Selected spinous tubercles on lateral surface of tail:	
Length to spine:	
Sl_1; Sl_2—first lateral right; second	1325; 1363
Sl_3; Sl_4—first lateral left; second	1348; 1365
K. Spines on ventral cutaneous keel:	
Length to series of spines on external margin; length of series	1744; 78
Maximum width of midlateral band of spines	18
Approximate maximum length of midlateral spine	1
L. Spots on lateral surface of disc:	
Approximate length to origin of: *x*, the prescapular segment of the line of spots; *y*, anterior postscapular segment; *z*, posterior postscapular segment	300; 600; 806
Transverse interval between paired rows at: origin of *x*; junction of *x* and *y*; junction of *y* and *z*	655; 345; 370
Minimum distance (right row) of segment *x* from spiracle, d.m.; distance (right row), d.m., of junction of segments *x* and *y* from spiracle	118; 180
Modal diameter of spots	12

General description.—For convenience of comparison, the subjoined account follows, as closely as practicable, the detailed description by Garrick (1954) of his New Zealand specimen, a female of *LT* 64 inches; but it is considerably compressed by omission of all statements involving ratios calculable by reference to Table I: it should be worked through with the table at hand for constant consultation.

Body depressed, thick, subrhomboidal; snout with distinct, bluntly pointed tip. Head wide, not markedly differentiated from disc. Dorsal profile in front of eyes moderately concave. Tail stout, tapered (imperfect distally), tuberculate and spinous (details below); with large serrated spear. Disc with four spines: t_1 mesial, near base of snout-tip; t_2 behind, to right of, sharper than, t_1; t_3 in advance of, nearly as far from main antero-posterior axis as, right eye; t_4 in mesial line. Eyes small, lateral. Spiracles large, ovoidal, posterolateral to eyes. Gill slits smallish, sigmoid. Nostrils ovoidal, somewhat obliquely transverse. Broad subrectangular internasal flap, slightly wider posteriorly than anteriorly; lateral border markedly sinuate; posterolateral corner fairly acute; posterior edge slightly concave; a stout mesial frenulum. Mouth moderately proconvex. Upper lip with some indeterminate coarse pleats laterally: lower lip with conspicuous forwardly directed lobular projections, a single row of large and some scattered small ones mesially, two rows of small laterally. Both lips laterally bounded by incurving nasoral grooves. When the posterolateral corner of the internasal flap is lifted, three-quarters, or less, of the nasal sac is disclosed, its posteroexternal half being obscured by a second, smaller, forwardly directed flap: of the parallel cartilaginous slats articulated, at right angles, to the transversely oblique cartilaginous stringer, 10 were counted in about 13 mm. Teeth arranged in pavement, quincuncially, not in contact; occlusal surface slightly convex, finely rugose; no cusps noted: only those readily visible were observed, namely, 90-100 in three "rows" in upper jaw, 37 in lower jaw. A good approximation to the modal tooth shape in plan may be obtained thus: in circle draw two radii, meeting at 90°-100°, to represent posterolateral borders; as anterior border, draw flattish curve about midway between arc and chord, giving a lateral-anteroposterior ratio of about 1·6.

Pectorals wide, the anterior margin of each distinctly sinuous—in sequence backwards from base of snout-tip, slightly concave, convex, broadly concave, convex just before angle. Posterior margin evenly rounded; posterior angle bluntly convex. Pelvics with outer lateral margin slightly concave; posterior margin convex; inner lateral margins together forming a wide inverted U; external insertion making deep notch with pectoral.

General plan of vent slenderly ovate-acuminate, but this figure with its posterior border broadly notched mesially; a postanal gutter, deepest anteriorly, its hinder superficial boundary rounded, nicked mesially.

Tail depressed anteriorly, compressed posteriorly. When examined it comprised an intact proximal segment, *A*, followed by an almost severed segment, *B*, imperfect at tip, attached to *A* only by ligament, with the epithelium missing in places for a distance of several centimetres. Serrated spear imperfect proximally (indications of its origin near end of *A*) and distally: portion present adherent to tail. A mesial groove at presumed site of missing anterior part of spear, and behind attached portion. Ventral cutaneous caudal keel along whole of *B*, both its origin and termination missing: its maximum height near middle as preserved. Anterior to spear, in mid-dorsal row on tail six well-separated spinous tubercles or bucklers, t_5-t_{10}. Like t_1-t_4 on disc, each consists of a longitudinally ovoidal shield, from which rises a blunt boss, or, usually, a tolerably sharp spine (in t_5 serrated), from whose base ridges run radially to the (usually crenulate) external border. Besides larger tubercles t_1-t_{10}, others, varying considerably in size, occur on tail, as follows. Ventral surface: extensive anterior surface wholly bare and smooth: to present origin of ventral keel about 54 spines, set irregularly, more densely posteriorly; beside keel bare. Ventral cutaneous keel: posterior one-third carries very small spines along external margin, 32 on right, 28 on left; mostly in single irregular peripheral row, but a few set in a little from margin. Lateral surface: to end of *A*, on right side 69 spines, on left 40; on *B*, at first somewhat irregularly disposed, with some indications of 1, 2, or 3 rows, the larger chiefly anterior and superior; shortly becoming confined to a mid-lateral band; in 215 mm 85 spines. Dorsal surface: except for t_5-t_{10} essentially bare; anteriorly, however, some upper members of lateral series encroach marginally on dorsal surface.

Rays in pectoral about 23 (to angle) + 77; in pelvic about 22.

Dorsal surface of disc slate-grey, evenly gradated, darkest mesially. Two rows of whitish spots, subcircular, or somewhat elliptical, with major axis in most anteroposterior, but in some distinctly transverse. Each series comprises three contiguous segments: segment *x*, with 10-12 spots, begins about midway between spiracle and lateral margin of disc, or rather nearer latter, and runs backwards and inwards, roughly parallel to disc-margin, to scapular region; *y*, with 7-9 spots, a little sinuous, general direction anteroposterior, the two series somewhat convergent caudad, terminating about at beginning of last one-third of disc: *z*, with, on left, one well-defined rounded spot (largest on disc) followed by large anteriorly elongate patch, on right one similar patch only. Ventral surface of disc white, with, from level of mouth caudad, a narrow marginal band of purplish-black, its outer margin complete, its inner in general tolerably sharply defined, but in parts, particularly anteriorly, broken by, and bordered with, scattered islands of dark or darkish spots and splashes; narrowest at beginning, widest (about half mouth-width) at middle of disc or on pelvics. Upper surface of pelvics about concolorous with pectoral margins; lower surface white, with external dark band continued from pectorals sharply delimited internally. Segment *A* of tail: dorsally, dark-brown, darkest mesially; laterally, dark-brown; ventrally, wholly whitish to level of end of pelvics, thereafter whitish laterally (some

purplish mottling continued from sides), otherwise purplish, with some lighter mottling. Segment *B*: dorsally, dark-brown, fairly sharply delimited from sides; laterally, ranging from whitish to pale brownish; ventrally, chiefly whitish. Inferior caudal keel: anteriorly dark-brown in external one-third, rest whitish; a brown band gradually increasing in width posteriorly, finally involving whole keel.

Discussion.—It is not proposed to institute a detailed comparison with descriptions given by Garrick and others; but attention may profitably be called to a few major features: it is unfortunate that critical data are not available on dorsal keel, point of termination of ventral keel, maxillary velum, oral papillae, fimbriation of internasal flap. Generally speaking, the specimen agrees well with Garrick's *Maimai* female, with McCulloch's (1915) male from off Babel Island, and perhaps with *D. schreineri* (Gilchrist) as described by Barnard (1925 : 76). All (except possibly Whitley's example; point indeterminable from photo) have front pectoral margin slightly longer than hind. Noteworthy points in which the Tasmanian differs from the New Zealand example include: (*a*) more prominent snout-tip (Garrick states, however, a small projecting snout characterizes the type; it appears to be conspicuous in Whitley's (1940) fig. 227, and is evident in both McCulloch's (1915) plates); (*b*) shape of teeth (quite different also from Waite's photograph in Whitley: and lacking the cusps noted by McCulloch); (*c*) presence of tubercles on disc (*cf. D. agulhensis* Barnard, 1925; it seems possible, however, that while in Barnard's species the spines may be characteristic, they may here represent nothing more significant than three small additions to the spine in the middle of the back of the type: size and shape of tail differ notably from *D. aghulensis*); (*d*) presence of whitish spots (a similar pattern seems to be recognizable in Whitley's figs. 227, 228); (*e*) internasal valve widest posteriorly (as in McCulloch, pl. XVII); (*f*) various differences in proportion.

The very provisional conclusions derivable from this discussion are formulated in the table of synonymy. I have followed Fowler (1941), Smith (1950), Richardson and Garrick (1953), and Garrick (1954) in non-recognition of *Bathytoshia* Whitley, 1933. (Richardson & Garrick speak of difficulty arising from some measure of obscurity in the diagnosis. The palmary point, however, is procedural: *Bathytoshia* is established essentially by the differentiation of its orthotype, *Dasyatis thetidis* Waite, 1899, from *Dasyatis fluviorum* Ogilby, 1908, orthotype of *Toshia* Whitley, 1933, and not, as the case requires, by the differentiation of *D. thetidis* from *Dasyatis* Rafinesque, 1810, as specified primarily by its genotype, *D. ujo* Rafinesque.)

Family ECHELIDAE

In an earlier contribution in this series (1953) a key to the three Tasmanian echelids—*Muraenichthys breviceps* Günther, 1876, *M. tasmaniensis* McCulloch, 1911, *M. australis* Macleay, 1881—was provided, and some observations were made on an example of the first-named species. I have since been fortunate in securing five additional specimens of *M. breviceps;* a metrical examination of which yields the interesting result set out below.

Genus **MURAENICHTHYS** Bleeker, 1865

MURAENICHTHYS BREVICEPS Günther, 1876

Muraenichthys breviceps Günther, 1876, *Ann. Mag. Nat. Hist.* (4), XVII : 401.

Muraenichthys breviceps Günther. McCulloch, 1929, *Mem. Aust. Mus. Sydney*, V, 1 : 67. Scott, 1953, *Pap. Proc. Roy. Soc. Tasm.*, 87 : 146 (synonymy).

Material.—Six specimens: (*a*) *LT* 583, Tamar River at Blackwall, 5th July, 1935, Mr. Lyall; (*b*) *LT* 491, Stanley, received 28th February, 1938, Mr. B. Mollison; (*c*)-(*f*) *LT* 393·3, 370·5, 313·5, 234·8, respectively, from stomachs of ling, *Genypterus blacodes* (Bloch and Schneider, 1801), taken on long line in 250-300 fm, off Maatsuyker Island, "a few weeks" before date of receipt, 11th December, 1953, Mr. J. R. Cowper. The sample, it is seen, exhibits a considerable *LT* range: it is significantly symmetrical ($t = 0{\cdot}41$), and on a range/σ test falls well within the $P = 0{\cdot}05$ value for a random sample drawn from a normal population.

Linear regressions.—Analysis of this satisfactorily distributed sample reveals the existence of linear regressions of most of the important anatomical regions and of some diagnostic ratios on *LT*, head length, and so on. These results (Table II) are not only noteworthy in themselves, but would seem to be of special interest in view of the fact that precision measurements of numerically smaller samples, with narrower *LT* ranges, in several echelid genera recently studied by Schultz (1953) in general yield no clear evidence of comparably regular correlation.

For the taxonomist the interest of a regression equation commonly resides not only in the mere establishment of its formal validity, by means of a test of significance, but also in its degree of usefulness as an instrument of prediction in diagnosis: and while the essential information on the second point is of course inherent in a summary, formal guise in a *t*-value, it has seemed worthwhile to study in the table the convenience of the practising systematist by the inclusion, first, of each value of the dependent variable as calculated from the regression equation, and, secondly, in each equation, of the mean divergence, absolute and percentage (sign disregarded), of predicted from observed magnitude. It will be noticed that on several occasions a dimension appears in one equation as a unit (e.g., length to vent) and again in other equations as its components (head, trunk): this course has been followed to permit of direct comparison with data elsewhere in the literature.

Two points of interest emerge regarding what I have elsewhere (1953 : 142) designated Schmidt's index: first, it is here subject to systematic variation (I am not aware of any establishment of this circumstance in Anguillidae, the family for which it was devised); secondly, with a variation of less

TABLE II

Muraenichthys breviceps Günther, 1876. Linear regressions of lengths of certain body regions (and values of some ratios) on lengths of certain important body regions conventionally treated in diagnosis as independent variables. Six specimens: No. 1 Tamar River; No. 2 Stanley; Nos. 3-6 from stomachs of ling, *Genypterus blacodes* (Bloch & Schneider, 1801), off Maatsuyker Island. Observed measurements and directly calculated magnitudes are followed by predicted values in parentheses.

Variate and ratio	Specimen No. (and *LT*, mm)						Regression equation	t[1]	Error of predicted value on observed value	
	1 (583)	2 (491)	3 (393.3)	4 (370.5)	5 (313.5)	6 (234.8)			Mean error (mm or pure number)	Percentage error
Head on *LT*	44.0 (45.2)	40.0 (39.1)	34.5 (32.7)	30.4 (31.2)	27.5 (27.4)	21.3 (22.2)	$y=$ 0.06618x + 6.3	12.96	0.9	3.5
Length to vent on *LT*	221.8 (222.1)	187.0 (185.5)	146.5 (146.6)	137.0 (137.5)	112.0 (114.8)	85.5 (83.4)	$y=$ 0.3982x — 10.06	57.29	1.2	1.0
Trunk on *LT*	177.8 (176.9)	147.0 (146.3)	112.0 (113.9)	106.6 (106.3)	84.5 (87.4)	64.2 (61.3)	$y=$ 0.3320x — 16.69	40.00	1.3	1.8
Tail on *LT*	361.2 (360.9)	304.0 (305.5)	246.8 (246.7)	233.5 (233.0)	201.5 (198.7)	149.3 (151.4)	$y=$ 0.6018x + 10.07	81.80	1.2	0.6
Length to dorsal origin on *LT*	94.0 (95.5)	83.0 (80.8)	65.6 (65.2)	61.5 (61.5)	52.0 (52.4)	39.3 (39.8)	$y=$ 0.1605x + 2.07	23.06	0.8	1.1
Length to anal origin on *LT*	225.0 (228.7)	191.0 (186.8)	148.2 (148.0)	140.2 (138.9)	115.5 (116.3)	89.5 (85.0)	$y=$ 0.3973x — 8.27	63.57	2.5	1.8
Dorsal-anal interval on *LT*	131.0 (129.5)	108.0 (107.8)	82.6 (84.6)	78.7 (79.2)	63.5 (65.7)	50.2 (47.1)	$y=$ 0.2368x — 8.49	28.63	1.6	2.4
Schmidt's index [2]	21.92(21.85)	21.18(21.17)	20.57(20.45)	20.38(20.28)	19.14(19.85)	19.68(19.23)	$y=$ 0.007424x + 17.53	4.73	0.3	1.3
Snout on head	8.8 (9.1)	8.2 (8.4)	8.2 (7.3)	6.6 (6.5)	5.5 (5.9)	4.5 (4.7)	$y=$ 0.1968x + 0.48	6.48	0.4	5.0
Postorbital head on *LT*	32.8 (32.0)	28.9 (28.7)	22.7 (24.3)	20.7 (20.9)	18.8 (18.6)	14.2 (13.6)	$y=$ 0.8109x — 3.71	15.73	0.6	2.8
Postorbital head on head	32.8 (33.2)	28.9 (28.1)	22.7 (22.8)	20.7 (21.6)	18.8 (18.5)	14.2 (14.2)	$y=$ 0.05449x + 1.39	25.70	0.4	1.7
Eye-in-interorbital on *LT*	2.08(2.09)	1.72(1.73)	1.36(1.37)	1.29(1.28)	1.13(1.07)	0.73(0.77)	$y=$ 0.003777x — 0.12	27.58	0.02	2.1
Eye-in-interorbital on head	2.08(2.00)	1.72(1.78)	1.36(1.47)	1.29(1.24)	1.13(1.08)	0.73(0.73)	$y=$ 0.5594x — 0.46	12.89	0.1	3.7
Eye on head	2.4 (2.9)	2.9 (2.9)	3.6 (3.0)	3.1 (3.0)	3.2 (3.0)	3.6 (3.1)	$y=$ —0.009563x + 3.28	0.38	0.3	14.1
Eye on snout	2.4 (2.7)	2.9 (2.8)	3.6 (2.8)	3.1 (3.0)	3.2 (3.1)	3.6 (3.3)	$y=$ —0.1236x + 3.83	1.13	0.3	11.5
Eye on interorbital	2.4 (3.0)	2.9 (3.0)	3.6 (3.0)	3.1 (3.0)	3.2 (2.9)	3.6 (2.8)	$y=$ 0.08341x + 2.63	0.48	0.3	11.3
Maximum depth on *LT*	14.0 (15.7)	14.6 (12.7)	10.5 (10.0)	8.4 (9.3)	8.0 (7.8)	5.2 (5.6)	$y=$ 0.02792x — 1.00	6.06	0.9	8.5

[1] With D.F.=4, at $P=0.1$, $t=2.13$; $P=0.05$, $t=2.78$; $P=0.01$, $t=4.60$

[2] Schmidt's index, $S=\frac{L_v-L_d}{LT}$, where L_v=length to vent, L_d=length to dorsal origin; LT=total length.

than three units over an *LT* range of 348·2 mm, or 3·07 σ, it is relatively stable ($V = 4{\cdot}9$, $V^1 = 5{\cdot}5$) —in this context it thus appears to be a useful discriminant.

In the material examined, diameter of eye may be absolutely greater in smaller than in larger individuals: the same feature appears in precision measurements by Schultz (1953) of some other Echelidae, and is encountered also in the allied families Ophichthidae and Moringuidae. Several equations in Table II not specifying statistically significant linear relations have been included to illustrate the problem presented by this curious irregularity in eye-size.

Family ATHERINIDAE

In the Check List (McCulloch, 1929), seven atherines are accredited to Tasmania. Some of the early diagnoses are brief and inconclusive, and the data requisite for the satisfactory keying of our fauna are probably not at present available.

Genus **ATHERINA** Linné, 1758

ATHERINA MICROSTOMA Günther, 1861

Atherina microstoma Günther, 1861, *Cat. Fish. Brit. Mus.*, III : 91. Type locality: Tasmania.

Atherina microstoma Günther. Waite, 1923, *Fish S. Aust.*: 104, fig. on p. 105. McCulloch, 1929, *Mem. Aust. Mus. Sydney*, V, 1 : 108.

Occurrence.—About December-January this species is encountered in countless thousands round our eastern and western (and probably other) coasts. Very young individuals, in which the dull orange yolk sac may still be visible, are very pale greenish, almost transparent; the eye has a broad conspicuous silver annulus. They move slowly, almost at the surface, among weeds or over open sand in shallow water, commonly in schools of from a couple of score to a hundred or more. Specification of *LS* of a sample netted in The Arm, a long narrow inlet, with a river-like facies, in George's Bay, St. Helens, on 20th January, 1953: n 17; range 12·5-19·1; $\bar{x}$ 15·30 $\pm$ 0·49; σ 2·03 $\pm$ 0·35; V 13·3 $\pm$ 2·4. Larger individuals usually travel in smaller schools, and at a greater depth.

Nuptial attire.—In individuals manifesting the so-called nuptial attire, of which some account, based on material from the mouth of the Glenelg River, near the Victorian-South Australian border, has been given by Waite (1923 : 104), a blood-red bar, expanded somewhat at the hypurals, extends along the midflank, wholly replacing the normal silvery stripe, while, almost always, the whole eye also is a glittering blood-red. While this brilliant display is, indeed, probably associated, as Waite's term would indicate, with sexual activity, an examination of 12 samples, comprising in all 289 specimens collected at The Arm, George's Bay, on 3rd-24th January, 1953, reveals some puzzling features. From data set out in the protocol (Table III) it will be seen, first, that presence or absence of the marking does not appear to be necessarily a matter of mere size; secondly, that of samples caught on successive days one may be wholly affected and one wholly unaffected; thirdly, that preservation in alcohol commonly, but not invariably, elicits either the whole pattern, or, at times, only the lateral stripe (in, it may be added, varying degrees of intensity) from individuals devoid of it in life. It is not improbable the bright red pattern is, totally or sectionally, under hormonal control.

Postmortem mouth posture.—Attention was called earlier (1953 : 156) to specific differences in the relative postmortem positions of some of the mouth elements in the case of two common rock-pool fishes, *Bovichtus variegatus* Richardson, 1846, and *Pictiblennius tasmanianus* (Richardson, 1849) (derrised specimens). In one series of the present material intraspecific variation was observed. All specimens of a sample of 22 trapped on 22nd January, 1953, and left overnight in a bucket were dead next morning: 12 died with mouth wide open, fully protracted, incapable of being permanently closed; three with mouth open, but, after a little manipulation, capable of being restored temporarily to the normal retracted position; seven with mouth closed. As the accompanying protocol (Table IV) shows, postmortem mouth posture in this sample is significantly associated with size of fish. With the two subgroups of open-mouths pooled to give a twofold table for *LS* and mouth posture, adjusted χ^2 is 4·95.

Length of caudal.—While length of caudal is not a constant fraction of *LS*, and is hence not amenable to the familiar naïve formulation, "x is a in y" ($y = ax$), it is nevertheless, with very good statistical accuracy, a simple function of length of fish. However, whereas in another small locally-found fish, *Galaxias attenuatus* (Jenyns, 1842), the *LT*-*LS* relation has been shown (Scott, 1938 : 120) to be allometric ($LT = bLS^k$), it is here isogonic ($LT = mLS + k$), thus affording a further instance of the marked tendency towards form-constancy found, since the work of Hecht (1916), to be generally characteristic of fish. Data are exhibited in Table V, accompanied by the calculated magnitudes of *LT* given by the equation $LT = 1{\cdot}1568LS + 1{\cdot}03$, computed from actual means of *LS* classes (not class-marks) and unweighted *LT* means. As will be seen, the fit is extremely good ($t = 78{\cdot}72$). It has been thought expedient to employ a rather small class-interval ($h = 3$); well-filled terminal classes being sacrificed to gain as wide a range as practicable.

The range of variation of *LT* associated with a given magnitude of *LS* may be directly illustrated: for seven specimens of *LS* 36, *LT* is 40·9, 42·2, 42·5 (2), 42·7, 43·1 (2); for 5 of *LS* 34·9, *LT* is 39·2, 40·8, 41·1, 41·2 (2); for 5 of *LS* 40·0, *LT* is 47·0, 47·4, 47·9, 48·1 (2)—giving V 1·7, 1·9, 0·9, respectively.

Family BOVICHTIDAE

A key to Tasmanian members of the family has been given in a previous contribution 1953 : 155).

Genus **BOVICHTUS** Cuvier & Valenciennes, 1831.

Bovicthys variegatus Richardson, 1846, *Zool. Voy. Erebus and Terror, Fish.*: 56, pl. xxxiv, figs. 1-4. Type locality: Port Jackson.

Bovichiths roseo-pictus Hutton, 1904, *Trans N.Z. Inst.*, xxxvi : 148.

Bovichtus variegatus Richardson. McCulloch, 1929, *Mem. Aust. Mus. Sydney*, V, III 336. Scott, 1953, *Pap. Proc. Roy. Soc. Tasm.*, 87 : 155.

TABLE III

Atherina microstoma Günther, 1861. Presence or absence of nuptial attire before, and after, preservation in alcohol; 12 samples (289 specimens) from The Arm, George's Bay, St. Helens. Asterisk = color pattern present; zero = color pattern absent; dash = no record: first mark of reference specifies state before, second state after, preservation.

Standard length class (mm)	Sample No. and date											
	I 3/1/53	II 10/1/53	III 11/1/53	IV 11/1/53	V 13/1/53	VI 13/1/53	VII 16/1/53	VIII 17/1/53	IX 19/1/53	X 20/1/53	XI 22/1/53	XII 24/1/53
29–34	—	2**	2**	8⁰*	—	—	1⁰*	5⁰⁻	2⁰⁰, 1**	—	1⁰*	—
35–40	1**	11**	13**	26⁰*	1⁰⁻, 1*⁻	2⁰⁰	5⁰*, 2⁰⁰	27⁰⁻	7⁰⁰, 2**	4⁰⁻	6⁰*	—
41–46	—	10**	7**	3⁰*	9⁰⁻, 3*⁻	—	1⁰⁰	15⁰⁻	6⁰⁰	—	7⁰*	1⁰⁻
47–52	—	9**	1**	4⁰*	2⁰⁻	—	3⁰⁰	12⁰⁻	3⁰⁰, 1**	3⁰⁻	6⁰*	—
53–58	—	11**	1**	1⁰*	—	—	2⁰⁰	7⁰⁻	2⁰⁰	1⁰⁻	2⁰*	1⁰⁻
59–64	—	5**	—	1⁰*	—	—	1⁰⁰	5⁰⁻	—	—	—	—
65–70	—	2**	—	1⁰*	1⁰⁻	—	—	1⁰⁻	1⁰⁰	—	—	—
71–76	—	2**	—	1⁰*	—	—	1⁰⁰	1⁰⁻	—	—	—	—
77–82	—	1**	—	—	—	—	—	—	—	—	—	—
83–88	—	1**	—	—	—	—	—	—	—	—	—	—
Total	1	54	24	45	17	2	16	73	25	8(1)	22	2

(1) This sample included a ninth specimen of L_S 18.4 (no colour pattern).

TABLE IV

Atherina microstoma Günther, 1861. Postmortem mouth posture and size of fish (standard length); 22 specimens, trapped, The Arm, George's Bay, St. Helens, 22nd January, 1953. Double asterisk = mouth open and permanently protracted; single asterisk = mouth open and protracted, but retractable and closable; zero = mouth closed.

Standard length (mm)	Post mortem mouth posture	Standard length (mm)	Post mortem mouth posture	Standard length (mm)	Post mortem mouth posture
31.4	0	41.7	0	47.8	* *
35.2	*	42.0	*	49.0	* *
35.6	0	42.7	0	49.0	* *
37.3	0	43.6	* *	50.7	* *
37.4	0	44.6	* *	51.9	* *
38.2	0	45.2	* *	53.0	* *
39.3	0	47.3	* *		
41.1	*	47.8	* *		

TABLE V

Atherina microstoma Günther, 1861. Linear regression of total length (*LT*) on standard length (*LS*): predicted values of *LT* calculated from the equation: $LT = 1{\cdot}1568\ LS + 1{\cdot}03$ mm. Material (272 specimens) trapped; The Arm, George's Bay, St. Helens, January, 1953.

LS class (class mean)	No. of specimens	*LT*		*LS* class (class mean)	No. of specimens	*LT*		*LS* class (class mean)	No. of specimens	*LT*	
		Observed	Predicted			Observed	Predicted			Observed	Predicted
17–19 (18.4)	1	21.6	23.31	47–49 (48.24)	26	56.80	56.83	68–70 (69.97)	3	82.30	81.97
29–31 (30.98)	4	36.40	36.86	50–52 (51.44)	18	60.46	60.53	71–73 (72.40)	2	85.50	84.78
32–34 (33.63)	25	40.27	39.93	53–55 (54.46)	14	64.62	64.02	74–76 (75.60)	3	89.97	88.48
35–37 (36.19)	52	42.91	42.89	56–58 (57.16)	9	67.29	67.15	77–79 (78.1)	1	91.4	91.38
38–40 (39.34)	54	46.65	46.54	59–61 (60.48)	9	71.12	70.99	80–82 (83.2)	1	95.3	97.27
41–43 (42.32)	29	50.27	49.99	62–64 (63.23)	3	74.67	74.18				
44–46 (45.27)	16	53.63	53.39	65–67 (66.50)	2	76.40	77.96				

Juvenile characters.—A specimen of *LS* 30·5, *LT* 37·1, *i.e.*, rather less than one-seventh full grown—the smallest individual I have examined—obtained by derrising a rock pool at East Beach, Low Head, Northern Tasmania, on 14th December, 1953, shows several interesting ontogenetic features.

In the pectoral, ray 1 (uppermost) is simple; 2-8 are cleft distally; 9, 10 are scarcely divided; while 11-15 are simple, thickened throughout, bluntly pointed; but the extensive incision of the last few (usually five) interspaces that forms so characteristic a feature of the adult is represented only by two barely discernible scallopings at rays 13-14 and 14-15. In the distal half of the anal, however, emargination is fairly pronounced.

Complex color patterns, consisting essentially of more or less clearly developed alternate dark and light rows of spots, or imperfect bands, subparallel to free margin, that characterize all fins, except anal, in the adult are here present in very diverse stages of manifestation. From first dorsal caudad the normally patterned unpaired fins exhibit a negative gradient of ornamentation development. In the first dorsal pigmentation is quite extensive, and three or four interrupted cross bars are well marked: in the anterior half of the second dorsal are rudiments (visible only with lens) of three or four blackish bars; in the third one-fourth of fin a few very small chromatophores indicate the position of one or two bars; while in last one-fourth membrane and rays alike are virtually colorless: in the caudal only the submarginal dark bar is observable, being represented by two to eight (modally about six) minute melanophores along either border of each ray, the pigmentation being most advanced on the lateral rays (except outermost, which is either pigmented only along its external margin—superior ray; or wholly unpigmented—inferior ray), and being much less obvious on the central two or three. In the ventral there are small clusters of chromatophores at base of spine; also beyond, at, before middle of 1st, 2nd, 3rd rays, respectively. The beginnings of a dusky bar mark the pectoral base; and a few punctulations occur elsewhere, mainly near middle of fin.

The large size of the eye (3·0 in head) results in minimum distance of eye from preorbital being less than one-fourth, compared with adult ratio of about one-half, orbital diameter: and interorbital becomes disproportionately large, being 5·3 (in adult 8-10 in head).

Family DIODONTIDAE

The two Tasmanian representatives are a globe fish, *Atopomycterus nicthemerus* (Cuvier, 1818), and a javelin fish, *Allomycterus pilatus* Whitley, 1931: in all published local lists our javelin fish is identified, apparently incorrectly (Whitley, 1931 : 125), with *Diodon jaculiferus* Cuvier, 1818, which is a West Australian form. The eastern form has been described and figured by McCulloch (1921 *a*).

Key to Diodontidae Recorded from Tasmania

A. Spines slender, subcylindrical, two-rooted, movable; their modal length on midflank $\geq$ minimum depth of caudal peduncle; about 13 in longitudinal line from nostril to dorsal origin. D. *ca* 12. A. *ca* 12. Head $>$ ⅛ total length. Dorsal base $<$ twice minimum depth of caudal peduncle; $\leq$ eye ..... *Atopomycterus nicthemerus*

AA. Spines usually massive, a postpectoral pair somewhat depressed, the remainder compressed (often javelin-like); three-rooted, fixed (except two-rooted, movable postpectoral pair); their modal length on midflank $<$ minimum depth of caudal peduncle; about 7 in longitudinal line from nostril to dorsal origin. D. *ca* 16. A. *ca* 16. Head $\leq$ ⅛ total length. Dorsal base $>$ twice minimum depth of caudal peduncle; $>$ eye ..... *Allomycterus pilatus*

Genus **ALLOMYCTERUS** McCulloch, 1921

ALLOMYCTERUS PILATUS Whitley, 1931

Allomycterus pilatus Whitley, 1931, *Rec. Aust. Mus. Sydney*, xviii, 3 : 125. Type locality: New South Wales.

[*non*] *Diodon jaculiferus* Cuvier, 1818, *Mem. Mus. d'Hist. Nat. Paris*, IV : 130, pl. VII, central fig.

Chilomycterus jaculiferus (Cuvier). Johnston, 1883, *Pap. Proc. Roy. Soc. Tasm.* (1882): 136. Johnston, 1891, *Pap. Proc. Roy. Soc. Tasm.* (1890) : 17.

Allomycteris jaculiferus (Cuvier). McCulloch, 1921, *Rec. Aust. Mus. Sydney*, xiii, 4 : 141, pl. xxxiii, fig. 2. Lord, 1923, *Pap. Proc. Roy. Soc. Tasm.* (1922) : 72. Lord and Scott, 1924, *Synopsis Vert. Anim. Tasm.*: 95.

[*part.*] *Allomycterus jaculiferus* (Cuvier). McCulloch, 1929, *Mem. Aust. Mus. Sydney*, V, iii : 434—eastern Australian records (N.Z.?).

Occurrence.—Though, unlike *Atopomycterus nicthemerus*, this species does not appear—*fide* Johnston (1883 : 136, 137)—in Allport's MS List, Johnston himself notes "common". It is, however, either much less abundant, or more local, than the slender-spined species. Along the North-West Coast I have encountered, over many years, scores of beach-dried examples of the latter, but I have secured only one javelin fish, a fairly freshly stranded specimen found on East Beach, Ulverstone, on 13th February, 1955.

Fin counts and dimensions.—D. 16. A. *ca* 15. P.? C. 9. *LS* 280. Length to origin of: pectoral *ca* 100, dorsal 215, anal 220. Fin base, between parallels, direct: dorsal 33, 36; anal 24, 25. Snout 24. Horizontal, vertical diameter of orbit 25, 28. Bony interorbital 51 anteriorly, 78 posteriorly. Internarial distance 34. Depth 125.

Caudal rays.—The caudal exhibits a peculiarity that appears to have been generally overlooked. The hard hyaline fin rays are either divided, or very readily fissile, throughout their whole length, in the sagittal plane. Attention has been called elsewhere in these studies (1953 : 161) to the existence of a similar condition in *Brachionichthys hirsutus* (Lacépède, 1804).

Spines.—As Waite (1923 : 229) justly observes, whereas the globe fish is defended directly by its long movable two-rooted spines, the javelin fish is protected mainly by the cuirass formed by the relatively large and massive roots by which all spines save two are held immovable. In the collapsed skin, from which there were recovered 218 perfect and 2 imperfect spines, the imbrication of the roots had led to the production of a lattice of remarkable complexity and strength.

Considering them simply in terms of mere location, and disregarding strains resultant upon muscular stresses, we may probably regard all the spines, without exception, as a series of three-dimensional solutions of the problem of the projection on to the complex surface of a bilaterally symmetrical subprolatum of an archetypal plane triradial root system, with the paired shorter limbs collinear, and the azygous (anatomically, cephalad) root normal to them; to which radical complex the spine is added primitively as a fourth radial element collinear with, and in sense opposite to, the unpaired root (for its plane of development, see below).

A formal analysis of observed modifications of the basic plan has been made, and has been found to involve 40 categories, with the lowest infracategory at the fifth level of subordination. It will suffice here to call attention to a few of the chief features of interest. For convenience of description, let a typical item be oriented in the same relation to the observer as the inverted typographical mark of reference, the dagger (†), on the page: the azygous root (*a*) will be taken to be directed forwards, and the spine (*s*) backwards, while the paired roots will be right (*r*) and left (*l*). Then with *a*, *r*, *l* coplanar and the system symmetrical, *r* and *l* may become convergent backwards (at most to a slight degree; more pronouncedly when *r* and *l* are curved), or forwards (modally to about 160°; minimum angle 65°) : asymmetry may be introduced by inequality of angles made by *r* with *a* and by *l* with *a* (maximally, one about thrice the other), by variations in relative shape and size of *r* and *l*, by curvature of *r*, *l*, or *a*, by combinations of these modifications, and so on. When we come to deal with three dimensions, the situation obviously becomes highly complex: in general, if *a*, the lower surface of which is rectilinear or very nearly so, is taken to be in the primitive plane, *r* and *l* are bent downwards, modally to about the same extent. Roots are frequently somewhat spatulate distally; if to varying degrees, least so in *a*.

When typically developed, *s* appears to be essentially a continuation forward of *a*; though it may, and commonly does, have a conspicuous hyaline rootlike substructure extending not only along *a*, but also, and at but little lower level of development, along each of *r* and *l*, the inferior junction of the three usually forming a small transverse slot or shallow cavity. Among the larger items, *s* is large (from basal slot to tip about one-third *a*), strongly compressed, straight, lanceolate, its tip about as high above slot as latter is above level of tips of *r* and *l*, so that it projects well beyond anterior borders of *a* and *l*. Among smaller items, it tends to be relatively shorter and less compressed, to have anterior border concave, and to be set at a greater (though variable) angle to *a*, so that its tip often fails to reach anterior root-contour. In four pairs of items, *s* has been subject to a torsion that results in its coming to lie virtually along *r* or *l*: in one of these pairs (from caudal peduncle) *s* is very large, its length from slot (17) being subequal to length of *r* or *l*.

The two anomalous movable postpectoral spines, which are commonly said to be two-rooted, are, indeed, virtually so: each, however, has a rudiment, or (in the light of the interpretation of the pattern advanced above, perhaps more probably) a vestige, of a third root. In both, *s* is slenderly pointed, much depressed proximally, slightly depressed distally; in lateral view gently sigmoid.

It was suggested above that the archetypal triradiate root system was plane; the question of the plane of the fourth element, the spine, being left open. Now, a coplanar system of four elements, of which three are roots and one a spine, would clearly have no, or little, functional value if set, as the case requires, in the integument subparallel to its surface. Hence, for a radical constellation so disposed, the spine-tip must rise above the root-plane. However, it is of much interest to note that in the "two-rooted" spines *r*, *l*, and *s* and the minute *a* are effectively coplanar; the erection and depression of *s* being brought about by rotation of the $(r + l)$ spindle, a movement uninhibited by the degenerate *a*. Hence we may perhaps regard two-dimensional symmetry as formally prior to three-dimensional.

Length of unpaired root, measured from its junction with anterior border of paired roots: *n* 216; range 7·8-31·1; $\bar{x}$ 17·97 $\pm$ 0·33; σ 4·79 $\pm$ 0·023; *V* 26·6 $\pm$ 1·3. Span (direct from tip to tip) of paired roots: *n* 216; range 9·4-45·1; $\bar{x}$ 24·43 $\pm$ 0·58; σ 8·47 $\pm$ 0·041; *V* 34·7 $\pm$ 1·7.

In view of the relatively self-sufficient character of *a*, it might be expected that the distribution of its length would approximate the normal. Calculation gives g_1 0·087 $\pm$ 0·17, g_2 — 0·28 $\pm$ 0·33; the departures from normality (platykurtosis, positive asymmetry) being non-significant (t = 0·52, 0·87). On the other hand, variation in the span $(r + l)$ is clearly likely to be complex, being dependent on a number of variables, of which some have been noted above; and it is found the frequency distribution shows pretty clear indication of being multimodal, with a primary mode at 25, tolerably well-marked subsidiary modes at 16, 34, and perhaps another at 42.

ADDENDUM

It is noted above (p. 1) that *Dasyatis brevicaudatus* (Hutton) is not recorded for Tasmania by McCulloch (1929) or Whitley (1940), and it is suggested that the individual here described provides perhaps the first formal record for this State. While this paper has been in press, the section on the family *Dasyatidae* in Mr. I. S. R. Munro's *Handbook of Australian Fishes* (now appearing in parts in the *Fisheries Newsletter*) has been published: localities there given for this species are New South Wales, Victoria, South Australia, Tasmania, southern Western Australia.

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THE TASMANIAN REPRESENTATIVES OF THE PTERIDOPHYTA

By

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(Communicated by Dr. Winifred Curtis)

This paper presents an enumeration and classification of the pteridophytes which are known to occur naturally in Tasmania. Authorities are cited for specific names and binomials, and publication data are set out in connection with each species. Basic synonyms are noted, and there is indicated also the manner in which each species was dealt with in the following five major botanical works:

Novae Hollandiae plantarum specimen—Part 2, by J. J. Labillardière (1806).

Prodromus Florae Novae-Hollandiae et Insulae Van Diemen, by Robert Brown (1810).

Flora Tasmaniae—Part 2, by J. D. Hooker (1860).

Flora Australiensis—Part 7, by George Bentham (1878).

The Tasmanian Flora, by Leonard Rodway (1903).

The arrangement used is that set out for the Pteridophyta in the Cambridge University publication, *A Classification of Plants* (1938), with however, the "*Polypodiaceae*" (as in that work) divided up into the families suggested by A. H. G. Alston in the paper entitled "The Subdivision of the Polypodiaceae" in *Taxon*. 5[2]: 23-25 (1956).

Neither diagnoses nor distribution data are included here, for they are available, together with illustrations of each species, in the book *Ferns of Victoria and Tasmania**, to which the present paper is complementary. [In this book however, a major part of the classification is on the lines set out by R. E. Holttum in "A revised classification of the Leptosporangiate ferns", in *Journ. Linn. Soc. London* 53: 123-158 (1947).]

The 83 local species are probably satisfactorily delimitated now, but the nomenclature of some of them requires further study and some adjustment.

Division PTERIDOPHYTA

Order PSILOTALES

Family PSILOTACEAE

TMESIPTERIS Bernh.

T. BILLARDIERI Endl. *Prod. Fl. Norf.*: 6 (1833).

Based on the Tasmanian material dealt with by Labill. (*l.c.*: 105 T.252) as belonging to *T. tannensis* (Spreng.) Bernh.

Treated by Hook. f. (*l.c.*: 155) as belonging to *T. forsteri* Endl., and by both Benth. (*l.c.*: 680) and Rodway (*l.c.*: 280) as belonging to *T. tannensis*, these names being used comprehensively in each case to cover all known material of the genus. [See *Vict. Nat., Melb.* 60: 142 (Jan. 1944).]

T. TUGANA H. N. Barber *Vict. Nat., Melb.* 71: 98 (Oct. 1954).

Order LYCOPODIALES

Family LYCOPODIACEAE

PHYLLOGLOSSUM Kunze

P. DRUMMONDII Kunze *Mohl et Schlecht., Bot. Ztg.* 1: 721 (1843).

LYCOPODIUM Rupp.

L. SCARIOSUM Forst. *Fl. Ins. Austr. Prod.*: 87 (1786).

Syn. *L. decurrens* R.Br. *l.c.*: 165.

L. DEUTERODENSUM Herter *Index Lycopod.*: 15 (1949).

Syn. *L. densum* Labill. *l.c.*: 104 T.251 fig. 1; R.Br. *l.c.*: 165; Hook, f. *l.c.*: 156; Benth. *l.c.*: 676; Rodway *l.c.*: 280; non *L. densum* Lam. (1788).

L. FASTIGIATUM R.Br. *l.c.*: 165.

Syn. *L. clavatum* var. *magellanicum* (Swartz) Hook. f. *Fl. Antarct.* 1: 113 (1844); *Fl. Tasm.* 2: 157.

L. clavatum var. *fastigiatum* (R.Br.) Benth. *l.c.*: 675; Rodway *l.c.*: 280.

L. LATERALE R.Br. *l.c.*: 165.

Including *L. diffusum* R.Br. *l.c.*: 165; Benth. *l.c.*: 675. Syn. *L. laterale* var. *diffusum* (R.Br.) Hook. f. *Fl. Nov.-Zel.* 2: 54 (1855); *Fl. Tasm.* 2: 156.

L. SELAGO L. *Sp. Pl.* 2: 1102 (1753).
It is very doubtful however whether this Australasian material is rightly identified with that of the Northern Hemisphere.

L. VARIUM R.Br. *l.c.*: 165.

Included with *L. selago* L., by Rodway (*l.c.*: 280).

L. CAROLINIANUM L. *Sp. Pl.* 2: 1102 (1753).

The recording of this species for Tasmania, by Hook. f. (*l.c.*: 170) and Benth. (*l.c.*: 675), was discredited by Rodway (*l.c.*: 280), but it was finally upheld in *Vict. Nat., Melb.* 65: 281 (Apr. 1949).

* Published by the Field Naturalists Club of Victoria (Melbourne, 1955) and obtainable from the Hon. Secretary: F.N.C.V., National Herbarium, South Yarra, S.E.1. Victoria; price 7s. 6d. posted.

Family SELAGINELLACEAE

SELAGINELLA Beauv.

S. ULIGINOSA (Labill). Spring *Mém. Acad. Roy. Sci., Brux.* 15: 60 (1842).

Syn. *Lycopodium uliginosum* Labill. *l.c.*: 104 T.251 fig. 2; R.Br. *l.c.*: 165.

S. PREISSIANA Spring *l.c.*: 61.

Family ISOËTACEAE

ISOËTES L.

I. GUNNII A.Br. *Moatsb. Kön. Akad. Wiss., Berlin* Aug. 1868: 535 (1868).

Listed as "*Isoëtes* sp." by Hook. f. (*l.c.*: 158).

I. DRUMMONDII A.Br. *l.c.* 1863: 559 (1863).

Discovered in the north of Tasmania, near George Town, since the publication of *Ferns of Victoria and Tasmania.*

I. HUMILIOR F.Muell. ex A.Br. *Linnaea, Halle* 25: 722 (1852).

I. ELATIOR F.Muell. ex A.Br. *l.c.*

[All the Tasmanian material of this genus was included with the European *I. lacustris* L., by Benth. (*l.c.*: 671) and Rodway (*l.c.*: 279.)]

Order FILICALES

Family OPHIOGLOSSACEAE

OPHIOGLOSSUM L.

O. CORIACEUM A.Cunn. *Hook., Comp. Bot. Mag.* 2: 361 (1837).

Included with the tropical *O. gramineum* Willd., by R.Br. (*l.c.*: 163); included with the Old World *O. vulgatum* L., by Hook. f. (*l.c.*: 153 T.169) and by Benth. (*l.c.*: 688); and included with the northern *O. lusitanicum* L., by Rodway (*l.c.*: 281).

BOTRYCHIUM Swartz

B. LUNARIA (L.) Swartz *Schrad., J. Bot., Göttingen* 1800[2]: 110 (1801).

Syn. *Osmunda lunaria* L. *Sp. Pl.* 2: 1064 (1753).

B. AUSTRALE R.Br. *l.c.*: 164.

Included with the Asiatic *B. ternatum* (Thunb.) Swartz, by Benth. (*l.c.*: 690) and by Rodway (*l.c.*: 281); and included with the European and American *B. virginianum* (L.) Swartz, by Hook. f. (*l.c.*: 154 T.169).

Family OSMUNDACEAE

TODEA Willd.

T. BARBARA (L.) T.Moore *Index Fil.*: cxix (1857).

Syn. *Acrostichum barbarum* L. *Sp. Pl.* 2: 1072 (1753).

Osmunda barbara (L.) Thunb. *Prod. Fl. Cap.*: 171 (1800); R.Br. *l.c.*: 163.

Todea africana Willd. *Schr. Akad. Erf.* 1: 14 T.3 fig. 1 (1802); Hook. f. *l.c.*: 153 T.168.

Family SCHIZAEACEAE

SCHIZAEA Sm.

S. FISTULOSA Labill. *l.c.*: 103 T.250 fig. 3.

Included with *S. bifida* Willd., by Hook. f. (*l.c.*: 152).

S. BIFIDA Willd. *Schr. Akad. Erf.* 1: 30 T.3 fig. 3 (1802).

S. ASPERULA N.A.Wakefield *Vict. Nat., Melb.* 59: 89 (1942).

The descriptions, under *S. bifida* Willd., by R.Br. (*l.c.*: 162) and by Rodway (*l.c.*: 290), apply at least in part to this species.

Family GLEICHENIACEAE

GLEICHENIA Sm.

G. CIRCINNATA Swartz *Schrad., J. Bot., Göttingen* 1800[2]: 107 (1801).

Syn. *G. dicarpa* R.Br. *l.c.*: 161; Hook. f. *l.c.*: 131; Benth. *l.c.*: 698; Rodway *l.c.*: 289.

G. ALPINA R.Br. *l.c.*: 161.

Syn. *G. dicarpa* var. *alpina* (R.Br.) Hook. f. *l.c.*: 131.

Included by Benth. (*l.c.*: 698) with *G. dicarpa* R.Br. (= *G. circinnata* Swartz), and not distinguished by Rodway (*l.c.*).

G. MICROPHYLLA R.Br. *l.c.*: 161.

Erroneously identified as *G. circinata* Swartz [*sic*], by Benth. (*l.c.*: 697) and Rodway (*l.c.*: 289).

G. ABSCIDA Rodway *l.c.*: 289.

STICHERUS Presl

S. TENER (R.Br.) Ching *Sunyatsenia* 5: 283 (1940).

Syn. *Gleichenia flabellata* var. *tenera* (R.Br.) Hook. f. *l.c.*: 131; Benth. *l.c.*: 698.

Included with the mainland Australian *S. flabellatus* (R.Br.) St John (as *Gleichenia flabellata*) by Rodway (*l.c.*: 289). This latter apparently does not occur in Tasmania, despite the recording of it for the Island by R.Br. (*l.c.*: 161), Hook. f. (*l.c.*: 131) and Benth. (*l.c.*: 698). [See *Vict. Nat., Melb.* 60: 110 (Nov. 1943).]

Family HYMENOPHYLLACEAE

The classification adopted here for this family is that of E.B.Copeland in *Philipp. J. Sci.* 67 (1938).

HYMENOPHYLLUM Sm.

H. CUPRESSIFORME Labill. *l.c.*: 102 T.250 fig. 2.

Syn. *H. tunbridgense* var. *cupressiforme* (Labill.) Hook. f. *l.c.*: 153.

Included with the European and African *H. tunbridgense* (L.) Sm., by R.Br. (*l.c.*: 159), Benth. (*l.c.*: 706) and by Rodway (*l.c.*: 290).

H. PELTATUM (Poir.) Desv. *Mém. Soc. Linn., Paris* 6: 333 (1827).

Syn. *Trichomanes peltatum* Poir. *Encycl. méth. Bot.* 8 : 76 (1808).

H. unilaterale Willd. *Sp. Pl.* (*ed.* 4) 5: 521 (1810); Hook. f. *l.c.*: 133.

H. wilsonii Hook. *Brit. Fl.* 1 : 446 (1830); Rodway *l.c.*: 290.

MECODIUM Presl ex Copeland

M. FLABELLATUM (Labill.) Copeland *l.c.*: 21.

Syn. *Hymenophyllum flabellatum* Labill. *l.c.*: 101 T.250 fig. 1; Hook. f. *l.c.*: 134; Benth. *l.c.*: 705; Rodway *l.c.*: 290.

Hymenophyllum nitens R.Br. *l.c.*: 159.

M. RARUM (R.Br.) Copeland *l.c.*: 24.

Syn. *Hymenophyllum rarum* R.Br. *l.c.*: 159; Hook. f. *l.c.*: 134; Benth. *l.c.*: 705; Rodway *l.c.*: 290.

M. AUSTRALE (Willd.) Copeland *l.c.*: 24.

Syn. *Hymenophyllum australe* Willd. *Sp. Pl.* (*ed.* 4) 5: 527 (1810).

Erroneously identified as *Hymenophyllum flabellatum* Labill. by R.Br. (*l.c.*: 159).

Included with *Mecodium javanicum* (Bl.) Copeland, by Benth. (*l.c.*: 706) and by Rodway (*l.c.*: 290), in each case as *Hymenophyllum javanicum*; and included with *M. crispatum* (Wall. ex Hook. et Grev.) Copeland, by Hook. f. (*l.c.*: 134), as *Hymenophyllum crispatum*—both these being tropical species.

[*M. intricatum* (v.d.Bosch) Copeland *l.c.* 22—Syn. *Hymenophyllum intricatum* v.d.Bosch *Ned. kr. Arch* 5[3]: 168 (1863) is unknown to the present author though Copeland listed it as endemic in Tasmania.]

CRASPEDOPHYLLUM Copeland

C. MARGINATUM (Hook. et Grev.) Copeland *l.c.*: 27.

Syn. *Hymenophyllum marginatum* Hook. et Grev. *Icon. Fil.*: T.34 (1828); Rodway *l.c.*: 290.

APTEROPTERIS Copeland

A. MALINGII (Hook.) Copeland *l.c.*: 35.

Syn. *Trichomanes malingii* Hook. *Gard. Ferns*: T.64 (1862).

Hymenophyllum malingii (Hook.) Mett. *Abh. senskenb. naturf. Wiss* 7: 489 (1864); Rodway *l.c.*: 290.

POLYPHLEBIUM Copeland

P. VENOSUM (R.Br.) Copeland *l.c.*: 55.

Syn. *Trichomanes venosum* R.Br. *l.c.*: 159; Hook. f. *l.c.*: 135; Benth. *l.c.*: 702; Rodway *l.c.*: 289.

Family CYATHEACEAE

CYATHEA Sm.

C. CUNNINGHAMII Hook. f. *Hook., Icon. Pl.*: T.985 (1854).

Included with the New Zealand *C. medullaris* (Forst.) Swartz, by Benth. (*l.c.*: 708).

C. AUSTRALIS (R.Br.) Domin *Pteridophyta*: 262 (1929).

Syn. *Alsophila australis* R.Br. *l.c.*: 158; Hook. f. *l.c.*: 132; Benth. *l.c.*: 710; Rodway *l.c.*: 289.

Family DICKSONIACEAE

DICKSONIA L'Herit.

D. ANTARCTICA Labill. *l.c.*: 100 T.249.

Family ADIANTIACEAE

ADIANTUM L.

A. AETHIOPICUM L. *Syst. Nat.* (*ed. X*) 2: 1329 (1759).

Syn. *A. trigonum* Labill. *l.c.*: 99 T.248 fig. 2.

A. assimile Swartz *Schrad., J. Bot., Göttingen* 1800[2]: 83 (1801); R.Br. *l.c.*: 155.

CHEILANTHES Swartz

C. TENUIFOLIA (Burm.) Swartz *Syn. Fil.*: 129, 332 (1806).

Syn. *Trichomanes tenuifolium* Burm. *Fl. Ind.*: 237 (1768).

PELLAEA Link

P. FALCATA (R.Br.) Fée *Gen. Fil.*: 129 (1852).

Syn. *Pteris falcata* R.Br. *l.c.*: 154; Hook. f. *l.c.*: 139; Benth. *l.c.*: 287.

Platyloma falcata (R.Br.) J.Sm. *J. Bot., London* 4: 160 (1841); Rodway *l.c.*: 287.

PTERIS L.

P. COMANS Forst. *Fl. Ins. Austr. Prodr.*: 79 (1786).

Syn. *Litobrochia comans* (Forst.) Presl *Tent. Pteridogr.*: 149 (1836); Rodway *l.c.*: 285.

P. endlicheriana Agardh *Recens. Gen. Pterid.*: 66 (1839); Hook. f. *l.c.*: 141.

P. TREMULA R.Br. *l.c.*: 154.

ANOGRAMMA Link

A. LEPTOPHYLLA (L.) Link *Fil. Sp. Cult.*: 137 (1841).

Syn. *Polypodium leptophyllum* L. *Sp. Pl.* 2: 1092 (1753).

Grammitis leptophylla (L.) Swartz *Syn. Fil.*: 23, 218 T.1 fig. 6 (1806); Benth. *l.c.*: 776.

Gymnogramma leptophylla (L.) Desv. *Berl. Mag.* 5: 305 (1811); Hook. f. *l.c.*: 151; Rodway *l.c.*: 286.

Family DENNSTAEDTIACEAE

HYPOLEPIS Bernh.

H. RUGOSULA (Labill.) J.Sm. *Bot. Mag.* 72: Compendium 8 (1846), as "*rugulosa*".

Syn. *Polypodium rugosulum* Labill. *l.c.*: 92, T.241; R.Br. *l.c.*: 147; Hook. f. *l.c.*: 149 (as "*rugulosum*").

Included with the mainland Australian and Asiatic *H. punctata* (Thunb.) Mett., by Benth. (*l.c.*: 764) and by Rodway (*l.c.*: 287)—in each case as *Polypodium punctatum*.

The Tasmanian material recorded by Hook. f. (*l.c.*: 138) and by Rodway (*l.c.*: 287) as belonging to the tropical *H. tenuifolia* (Forst.) Bernh., would be actually of *H. rugosula*.

H. MUELLERI N. A. Wakefield *Vict. Nat., Melb.* 60: 42 (July 1943).

The recognition of this mainland Australian species from Smithton (Specimen: Herb. Univ. Tasm.) constitutes a new record for Tasmania.

H. PUNCTATA (Thunb.) Mett. *Kuhn, Fil. Afr.*: 120 (1868).

Syn. *Polypodium punctatum* Thunb. *Fl. Jap.*: 337 (1784).

This species is included here, actually as a new record for Tasmania, on the authority of J. H. Willis of the National Herbarium of Victoria, who reports observing it near Strzelecki Peaks on Flinders Island in April 1954.

H. AUSTRALIS N. A. Wakefield *Vict. Nat., Melb.* 72: 95 (Oct. 1955).

CULCITA Presl

C. DUBIA (R.Br.) Maxon *J. Wash. Acad. Sci.* 12: 458 (1922).

Syn. *Davallia dubia* R.Br. *l.c.*: 157; Benth. *l.c.*: 716; Rodway *l.c.*: 288.

Dicksonia dubia (R.Br.) Gaudich. *Voy. Autour du Monde, Freyc.*: 367 (1827); Hook. f. *l.c.*: 132.

PTERIDIUM Scopoli

P. ESCULENTUM (Forst.) Diels *Engl. et Prantl, Nat. Pfl.* 1⁴: 296 (1899).

Syn. *Pteris esculenta* Forst. *Pl. Escul.*: 74 (1786); Labill. *l.c.*: 95 T.244; R.Br. *l.c.*: 154.

Pteris aquilina var. *esculenta* (Forst.) Hook. f. *Fl. Nov.-Zel.* 2: 25 (1855); *Fl. Tasm.* 2: 139; Benth. *l.c.*: 731.

Included with the tropical and northern *P. aquilinum* (L.) Kuhn, by Rodway (*l.c.*: 284), as *Pteris aquilina*.

HISTIOPTERIS (Agardh) J.Sm.

H. INCISA (Thunb.) J.Sm. *Hist. Fil.*: 295 (1875).

Syn. *Pteris incisa* Thunb. *Prodr. Pl. Cap.*: 171 (1800); Benth. *l.c.*: 732; Hook. f. *l.c.*: 140.

Litobrochia incisa (Thunb.) Presl *Tent. Pteridogr.*: 149 (1836); Rodway *l.c.*: 285.

Pteris vespertilionis Labill. *l.c.*: 96 T.245; R.Br. *l.c.*: 154.

Family LINDSAYACEAE

LINDSAYA Dryand. ex Sm.

L. CUNEATA (Forst.) C.Chr. *Index Fil.*: 392 (1906).

Syn. *Adiantum cuneatum* Forst. *Fl. Ins. Austr. Prodr.*: 84 (1786).

L. cuneata var. *lessonii* (Bory.) Hook. f. *l.c.*: 136.

L. trichomanoides Dryand. *Tr. Linn. Soc.* 3: 43 T.11 (1797); Benth. *l.c.*: 720; Rodway *l.c.*: 284.

L. LINEARIS Swartz *Schrad., J. Bot., Göttingen* 1800²: 78 (1801).

[The *L. lanceolata* Labill. *l.c.*: 98 T.248 fig. 1 (= *Schizoloma ensifolium* J.Sm.) was recorded in error as originating in Van Diemen's Land.]

Family DAVALLIACEAE

RUMOHRA Raddi

R. ADIANTIFORMIS (Forst.) Ching *Sinensia* 5: 70 (1934):

Syn. *Polypodium adiantiforme* Forst. *Fl. Ins. Austr. Prodr.*: 82 (1786).

Aspidium capense (L.) Willd. *Sp. Pl.* (*ed.* 4) 5: 267 (1810); Benth. *l.c.*: 758.

Aspidium coriaceum (Swartz) Swartz *Schrad., J. Bot., Göttingen* 1800²: 40 (1801); R.Br. *l.c.*: 148.

Polystichum coriaceum (Swartz) Schott. *Gen. Fil.*: ad T.9 (1834); Hook. f. *l.c.*: 148; Rodway *l.c.*: 288.

Family ASPLENIACEAE

ASPLENIUM L.

A. OBTUSATUM Forst. *Fl. Ins. Austr. Prodr.*: 80 (1786).

Including *A. obtusatum* var. *minor* R.Br. *l.c.*: 150, a small form considered by Labill. (*l.c.*: 93 T.242 fig. 2) to be typical of the species.

The larger material, identified by Labill (*l.c.*: fig. 1) as *A. obliquum* Forst., is not considered separable from *A. obtusatum*.

A. FLABELLIFOLIUM Cav. *Descr. Pl.*: 257 (1802), as "*flavelifolium*".

A. TRICHOMANES L. *Sp. Pl.* 2: 1080 (1753).

A. BULBIFERUM Forst. *Fl. Ins. Austr. Prodr.*: 80 (1786).

Syn. *Caenopteris appendiculata* Labill. *l.c.*: 94 T.243.

A. laxum R.Br. *l.c.*: 151.

Including *A. bulbiferum* var. *laxum* Rodway *l.c.*: 286.

A. FLACCIDUM Forst. *Fl. Ins. Austr. Prodr.*: 80 (1786).

Including *A. bulbiferum* var. *pinnatum* Rodway and *A. bulbiferum* var. *hookerianum* Rodway, *l.c.*: 286.

[*A. lucidum* Forst., included doubtfully by Hook. f. (*l.c.*: 146), and *A. hookerianum* Colenso, are New Zealand species, neither of which is known to occur in Tasmania.]

PLEUROSORUS Fée

P. RUTIFOLIUS (R.Br.) Fée *Gen. Fil*: 180 (1852.)

Syn. *Grammitis rutifolius* R.Br. *l.c.*: 146; Benth. *l.c.*: 775.

Gymnogramma rutifolia (R.Br.) Desv. *Mém. Soc. Linn., Paris* 6: 213 (1827); Hook. f. *l.c.*: 151; Rodway *l.c.*: 286.

Family BLECHNACEAE

BLECHNUM L.

B. PATERSONII (R.Br.) Mett. *Fil. Hort. Bot. Lips.*: 64 T.4 figs. 4-10 (1856).

Syn. *Stegania patersonii* R.Br. *l.c.*: 152.

Lomaria patersonii (R.Br.) Spreng. *Syst. Veg.* (*ed.* 16) 4: 62 (1827); Hook. f. *l.c.*: 141; Benth. *l.c.*: 734; Rodway *l.c.*: 283.

B. PROCERUM (Forst.) Swartz *Schrad., J. Bot., Göttingen* 1800[2]: 75 (1801).

Syn. *Osmunda procera* Forst. *Fl. Ins. Austr. Prodr.*: 78 (1786).

Stegania procera (Forst.) R.Br. *l.c.*: 153.

Lomaria procera (Forst.) Spreng. *Syst. Veg.* (*ed.* 16) 4: 65 (1827); Hook. f. *l.c.*: 142; Rodway *l.c.*: 283.

Including *Lomaria procera* var. *minor* Hook. f. *l.c.*: 142.

Included, together with the following species, with the South African *B. capense* (L.) Schlecht., by Benth. (*l.c.*: 737), as *Lomaria capensis*.

This Australian material will probably prove distinct from the true *B. procerum*.

B. MINUS (R.Br.) Ettings. *Denkschr., Akad. Wiss., Wien* 23: 63 T.8 figs. 5, 12 (1864).

Syn. *Stegania minor* R.Br. *l.c.*: 153.

Lomaria procera var. *paludosa* Rodway *l.c.*: 283.

Included with the preceding species by Hook. f. (*l.c.*: 142) and, as noted thereunder, by Benth. (*l.c.*: 737).

B. NUDUM (Labill.) Mett. ex Luerss. *Flora*, 1876: 292 (1876).

Syn. *Onoclea nuda* Labill. *l.c.*: 96 T.246.
Stegania nuda (Labill.) R.Br. *l.c.*: 153.
Stegania falcata R.Br. *l.c.*: 153.

Included with the New Zealand *B. discolor* (Forst.) Keys., by Hook. f. (*l.c.*: 143), by Benth. (*l.c.*: 735) and by Rodway (*l.c.*: 283), in each case as *Lomaria discolor*.

B. LANCEOLATUM (R.Br.) Sturm. *Enum. Pl. Vasc. Crypt. Chil.*: 25 (1858).

Syn. *Stegania lanceolata* R.Br. *l.c.*: 152.

Lomaria lanceolata (R.Br.) Spreng. *Syst. Veg.* (*ed.* 16) 4: 62 (1827); Hook. f. *l.c.*: 143; Benth. *l.c.*: 736; Rodway *l.c.*: 283.

B. FLUVIATILE (R.Br.) Lowe ex Salomon. *Nomencl. Gefasskrypt.*: 115 (1883).

Syn. *Stegania fluviatilis* R.Br. *l.c.*: 152.

Lomaria fluviatilis (R.Br.) Spreng. *Syst. Veg.* (*ed.* 16) 4: 64 (1827); Hook. f. *l.c.*: 142 T.167; Benth. *l.c.*: 736; Rodway *l.c.*: 283.

B. VULCANICUM (Blume) Kuhn *Ann. Mus. Lugd.-Bat.* 4: 284 (1869).

Syn. *Lomaria vulcanica* Blume *Enum. Pl. Javae*: 202 (1828); Hook. f. *l.c.*: 143; Benth. *l.c.*: 735; Rodway *l.c.*: 283.

It is probable that this Australasian plant will prove to be specifically distinct from that of Java.

B. PENNA-MARINA (Poir.) Kuhn *Fil. Afr.*: 92 (1868).

Syn. *Polypodium penna marina* Poir. *Encycl. méth.* Bot. 5: 520 (1804).

Stegania alpina R.Br. *l.c.*: 152.

Lomaria alpina (R.Br.) Spreng. *Syst. Veg.* (*ed.* 16) 4: 62 (1827); Hook. f. *l.c.*: 144; Benth. *l.c.*: 736; Rodway *l.c.*: 283.

B. CARTILAGINEUM Swartz *Syn. Fil.*: 114, 312 (1806).

DOODIA R.Br.

D. CAUDATA (Cav.) R.Br. *l.c.*: 151.

D. MEDIA R.Br. *l.c.*: 151.

Syn. *D. caudata* var. *media* (R.Br.) Benth. *l.c.*: 742.

Included with the local *D. caudata* (Cav.) R.Br., by Hook. f. (*l.c.*: 147) and by Rodway (*l.c.*: 284).

Family ASPIDIACEAE

POLYSTICHUM Roth

P. PROLIFERUM (R.Br.) Presl *Tent. Pteridogr.*: 83 (1836).

Syn. *Aspidium proliferum* R.Br. *l.c.*: 147.

Included with the European *P. aculeatum* (L.) Schott., by Benth. (*l.c.*: 757), as *Aspidium aculeatum*; and included with the New Zealand *P. vestitum* (Forst.) Presl, by Hook. f. (*l.c.*: 148) and by Rodway (*l.c.*: 288).

LASTREOPSIS Ching

L. HISPIDA (Swartz) Tindale *Vict. Nat., Melb.* 73: 183 (1957).

Syn. *Aspidium hispidum* Swartz *Schrad., J. Bot., Göttingen* 1800[2]: 39 (1801); (listed for Victoria only by Benth. *l.c.*: 760).

Nephrodium hispidum (Swartz) Hook. *Sp. Fil.* 4: 150 (1862); Rodway *l.c.*: 287.

Polystichum hispidum (Swartz) J.Sm. *J. Bot., London* 4: 195 (1841); Wakefield *Ferns of Victoria and Tasmania*: 47 (1955).

L. SHEPHERDII (Kunze ex Mett.) Tindale *Vict. Nat., Melb.* 73: 182 (1957).

Syn. *Aspidium shepherdii* Kunze ex Mett. *Fil. Hort. Bot. Lips*: 94 (1856).

Included with the mainland Australian *L. decomposita* (R.Br.) Tindale, by Hook. f. (*l.c.*: 149) and by Rodway (*l.c.*: 287), in each case as *Nephrodium decompositum*, and by Benth. (*l.c.*: 758), as *Aspidium decompositum*.

Pending Tindale's publication on *Lastreopsis*, this species, and two others which do not occur in Tasmania, were placed in *Ctenitis* in *Ferns of Victoria and Tasmania* (p. 46). All three are now regarded as belonging to the former genus.

Family ATHYRIACEAE

DIPLAZIUM

D. AUSTRALE (R.Br.) N. A. Wakefield *Vict. Nat., Melb.* 58: 142 (Jan. 1942).

Syn. *Allantodia australis* R.Br. *l.c.*: 149.

Asplenium brownii J.Sm. *J. Bot., London* 4: 174 (1841); Hook. f. *l.c.*: 147.

Included with the African and Asian *Athyrium umbrosum* (Ait.) Presl, by Benth. (*l.c.*: 749), as *Asplenium umbrosum*.

Athyrium australe (R.Br.) Presl; Rodway *l.c.*: 286; Wakefield *Ferns of Victoria and Tasmania*: 29 (1955).

CYSTOPTERIS Bernh.

C. FRAGILIS (L.) Bernh. var. TASMANICA (Hook.) Hook. f. *l.c.*: 136 T.166.

Syn. *Cystopteris tasmanica* Hook. *Sp. Fil.* 1: 199 (1846).

This material was recorded by Benth. (*l.c.*: 752) and by Rodway (*l.c.*: 288) simply as *C. fragilis* (L.) Bernh., and Hook. f. recorded the species as well as the variety from Tasmania. It is probable that the Australasian material will eventually be distinguished as a separate species, in which case Hooker's name will be applied to it.

Family THELYPTERIDACEAE

CYCLOSORUS Link

C. PENNIGERUS (Forst.) Copeland *Gen. Fil.*: 143 (1947).

Syn. *Polypodium pennigerum* Forst. *Fl. Ins. Austr. Prodr.*: 82 (1786).

A new record for Tasmania: See *Vict. Nat., Melb.* 60: 173 (Mar. 1944), under the name *Dryopteris pennigera*.

Family GRAMMITIDACEAE

GRAMMITIS Swartz

G. BILLARDIERI Willd. *Sp. Fl.* (*ed.* 4) 5: 139 (1810).

Syn. *Grammitis australis* R.Br. *l.c.*: 146 (1810); Hook. f. *l.c.*: 151; Rodway *l.c.*: 286.

Polypodium australe (R.Br.) Mett. *Abh. senckenb. naturf. Ges.* 2[1]: 36 n.15 (1856); Benth. *l.c.*: 762.

CTENOPTERIS Blume

C. HETEROPHYLLA (Labill.) Tindale *Amer. Fern Journ.* 41[4]: 100 (1951).

Syn. *Grammitis heterophylla* Labill. *l.c.*: 90 T.239.

Polypodium grammitidis R.Br. *l.c.*: 147; Hook. f. *l.c.*: 150; Benth. *l.c.*: 764; Rodway *l.c.*: 287.

Family POLYPODIACEAE

PHYMATODES Presl

P. DIVERSIFOLIUM (Willd.) Pich.-Ser. *Webbia* 8: 222 (1951).

Syn. *Polypodium diversifolium* Willd. *Sp. Pl.* (*ed.* 4) 5: 166 (1810).

Polypodium billardieri R.Br. l.c.: 147.

Phymatodes billardieri (R.Br.) Presl *Tent. Pteridogr.*: 196 (1836); Hook. f. *l.c.*: 150; Rodway *l.c.*: 287.

Included with the New Zealand (and mainland Australian) *Phymatodes scandens* (Forst.) Presl, by Labill. (*l.c.*: 91 T.240), as *Polypodium scandens*; and identified as *Polypodium pustulatum* Forst., by Benth. (*l.c.*: 769), but this latter was discarded as a *species dubium* by Pichi-Sermolli (*l.c.*: 218).

Family SALVINIACEAE

AZOLLA L.

A. FILICULOIDES Lam. *Encycl. méth. Bot.* 1: 343 (1783).

Syn. *A. rubra* R.Br. *l.c.*: 167; Hook. f. *l.c.*: 158; Benth. *l.c.*: 680.

Family MARSILEACEAE

PILULARIA L.

P. NOVAE-HOLLANDIAE A.Br. *Mber. Kön. Akad. Wiss., Berlin, Oct.* 1863: 435 (? 1864).

Included with the European *P. globulifera* L., by Hook. f. (*l.c.*: 159), by Benth. (*l.c.*: 684) and by Rodway (*l.c.*: 291).

GEOLOGY OF THE WEST COAST RANGE OF TASMANIA, PART III

Porphyroid Metasomatism

By

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(With 6 Figures and 4 Plates)

(*Communicated by Professor S. Warren Carey*)

ABSTRACT

Quartz and felspar porphyries and associated greenschists of the West Coast Range are described. Felspar porphyries are considered to have originated by the felspathising of spilitic lavas, lava breccias and related greywackes during a period of progressive metamorphism. Metamorphic mineral assemblages of the greenschist and albite-epidote-amphibolite facies are recognized in the porphyries and are identified with increasing degrees of porphyritising of host rocks. Sharp contacts between chlorite-sericite schists and quartzites are regarded as metamorphic in origin and as indicating the replacing action of a chloritising and sericitising front. Haematite rich rocks and low grade pyritic ores which respectively occupy narrow zones above and below the schist quartzite contact are regarded as representing minor haematising and pyritising fronts.

Sulphide and silicate metasomatism are closely related to the structure of the range and it appears that the advance of fronts has been engendered and controlled by the upward flow of heated waters through fault fissures and pore spaces. Metasomatic replacement was effected by diffusion and exchange through intergranular films. This mechanism is thermodynamically efficient and allows adequate explanations of growth, and also of corrosion structures, of quartz and felspar crystals in the porphyries. During the advance of fronts there was extensive transport of material; metamorphism was not merely an adjustment to changed isogradial conditions. In particular, migrating solutions leached iron, copper and sulphur from the basic rocks and precipitated them in specific zones where they now form low grade ores.

After a period of rising temperatures and progressive metamorphism there followed an interval of cooling and retreat of thermal zones. Because of the presence of abundant water there was during this cooling phase an intense retrograde metamorphism of the recently formed felspathic rocks. Hydration of these rocks resulted in the liberation of silica and thus gave rise to quartz porphyries and quartz sericite schists. Extreme pneumatolysis and leaching of silica from the porphyries gave rise to kaolinised rocks and to veins of quartz and chert. A similar kind of leaching of sulphides from the low grade ores, and of selective precipitation of sulphides in pipes and veins, gave rise to rich ore bodies.

INTRODUCTION

On Magmatism

Given all the information accumulated from the study of igneous rocks over the past hundred years one might expect that petrologists would be able to reach agreement on the mode or modes of origin of granites. It seems that differences of opinion probably stem in the first instance from the geographic isolation and consequent different geological environments and approaches of schools. A cursory examination of geological maps of Brittany (War Office, 1942) shows that the environment of the French school is one of stratiform or concordant "granites porphyroides" which readily lend themselves to stratigraphic and structural mapping, and whose study might readily lead to metasomatic hypotheses. The setting is the same in parts of Canada, Fennoscandia and Australia, and probably in Cornwall. In Scotland and in the Atlantic states of North America occur entirely different phenomena of dynamothermal metamorphism and cauldron subsidence complexes which respectively indicate certain limitations of diffusional metamorphism in the production of granites and point to magmatic origins. As a result much of the study of granites in those countries has centred round processes of crystallization and differentiation of fusion and assimilation, and metasomatism has until recently been ignored.

Considering the problem on a world-wide scale there is convincing evidence of both magmatic and metasomatic processes and the writer, in common with others, has no difficulty in believing that there are "granites and granites". That this account deals with phenomena typical of the Hercynian terrain of France must not, therefore, be taken to mean that the writer belongs to the "French school", nor that magmatic origins have been ignored. That it deals solely with metasomatic origins of porphyries must be taken to mean, instead, that the West Coast Range region constitutes a province which once suffered a particular kind of metamorphism.

Gradational Metamorphism

"Les considérations structurales l'étude des structures pre-existantes sont donc a la base des recherches sur la metasomatose". Wegmann (1948, p. 46).

An attempt has been made by the writer (Parts I and II, 1954 and 1956) to demonstrate that large bedding structures of sediments at Mount Lyell can be traced into metamorphic rocks and granites. Wegmann's statement applies to the finer bedding and particle (conglomeratic) structures of rocks also. Using these characters, independently of gross structures, many rocks which superficially appear to have been of magmatic origin can be demonstrated to be sedimentary and metamorphic. So far as the existence of such relict structures are concerned there is, for the writer, no problem of fact remaining. There are such rocks. They do show a gradational metamorphism, and the only problem concerning them is—what were the processes of metamorphism which brought them to their present state? There is no doubt, either, that such rocks exist in many parts of the world. From Vermont, Hitchcock (quoted by Winchell, 1888, p. 334) states "We define this rock as a conglomerate with a cement of syenite or granite, or as a syenite or granite with pebbles in it". From Canada, Brown (1948, p. 438) states "Contacts between sediments and porphyry are gradational and as the sediments are highly altered or 'porphyritised', it is often difficult to differentiate sediments from porphyry". From Minnesota, Winchell (1888, p. 219) says "Here is a real conglomerate . . . A real conglomerate . . . in a groundmass of typical syenite is certainly an extraordinary occurrence; I have never seen it before . . . never read of it" Emmons *et al* (1953, p. 116) . . . "The Wisconsin rapakivi granites . . . may be traced into rocks which we regard as metamorphosed greenstones".

Apart from the example cited here and in Part I of this work there are numerous other examples of such transitional rocks characterised by relict pebbles.

Metamorphic Contacts

There is also, for the writer, no problem of fact remaining as to the existence of sharp metamorphic contacts. The contacts at Mount Lyell between schist and quartzite, and on the Lynchford-Crotty track between porphyry and haematitic conglomerates are, from a structural viewpoint, indisputably metamorphic. (The writer would in these contexts allow no interpretations which did not explain the overall structures.)

Apart from the examples of Part I (*loc. cit.*) there are numerous cases described from many parts of the world. At one such sharp contact, below the unconformable Goodrich Quartzite of Michigan, Van Hise and Bailey (1897, p. 442) find a granite conglomerate in which "the matrix is completely crystalline . . . if it were not for the conglomeratic character of the rocks their sedimentary origin could not be asserted from the evidence shown by thin section". Below each of a succession of related overstepping unconformities (or transgressive contacts) associated with haematite, Van Hise finds much the same thing, e.i., below the Mesnard Quartzite (p. 224) and the Wewe Slate (p. 271). These and similar unconformities in America have been debated for sixty years (Lamey, 1937), and were debated even by Van Hise. . . . The apparent transition of the Mesnard quartzite into granite noted by Romminger, says Van Hise (1897, p. 239), is only due to mashing at the juncture of the two formations. "The mashing has transformed the clastic rock into a crystalline schist and metamorphosed the granite into a similar looking rock".

The sub-Bottnian unconformity, one of many in Fennoscandia (von Eckermann, 1936), has a similar lengthy history of debate. Sederholm (1934, p. 35) feels obliged to point out that "the occurrence of a conglomerate containing pebbles of gneiss is evidence of age that cannot be gainsaid", but he expresses his underlying doubt and reasons for saying this (p. 47) when he relates how, at contacts, granite "occasionally fills rounded cavities in the basic rock which have probably originated by the corroding action of the magma". Further reason is found in the writing of McCallien (1932, p. 271) on the sub-Bottnian unconformity. He quotes Sederholm thus, "Nobody who has any respect for facts could, standing before this contact, explain it by assuming that the diorite was younger than the schists". In face of this and of derived pebbles of diorite in the conglomerate McCallien (*loc. cit.*, p. 271) prefers to rely on intrusive stringers from the diorite; "the diorite" he says, "is younger, i.e., intrusive into the sediments".

Faced with the same kind of anomaly Wahl (1947), in an area he himself describes as granitised, overcomes the problem by supposing that quartz porphyry has been intruded along an unconformable contact and injected between the pebbles. He says (p. 190) that "the porphyry contains numerous xenoliths of older country rocks . . . often to a certain extent digested by the lava" and continues (p. 291), "it is, however, remarkable that these xenoliths only seem to occur as a fairly limited horizontal streak in the lava" (i.e., apparently retain an original bedded character).

According to Wegmann (1948, p. 46) Keilhau has it that "one must recognize the existence of phenomena before one attempts to explain them". In the works cited above is the recognition of the porphyroid problem. It is world-wide. We may now ask: what is porphyritising, how is it effected, why should it be associated with conglomerates and follow sedimentary boundaries, why should it result in sharp contacts, what is the meaning of the association spilite, porphyry, pyrite, haematite, and finally what is the relation of all these to major earth structures?

THE PORPHYROID CYCLE OF METAMORPHISM

Comparisons

The idea of metamorphic zones in regional metamorphism has long been established and the work of Becke, Grubenmann, Barrow, Van Hise and others has been broadened into a theory of metamorphic facies by Eskola (1920). This last concept treats metamorphism in terms of zones of chemical equilibrium at different temperatures and pressures in the earth, and defines a facies as all those rocks crystallizing with perfect equilibrium between minerals under one set of pressure-temperature conditions. In Harker's sense of regional

(dynamo-thermal) metamorphism the minerals which occur at a given depth are determined by pressure-temperature conditions in relation to the composition of the source rocks, and with little reference to transfer of material. In that view it is also considered that there has been little retrograde metamorphism and minerals now seen at the surface are metastable phases of minerals formed at the peak of anamorphism. These ideas of restricted metamorphism have tended to be attached to Eskola's (1920, p. 146) much broader concept which considers "minerals, quite regardless of their mode of crystallization, whether from magma or aqueous solution or gas . . . or by gradual change of earlier minerals". Porphyroid metamorphism fits into Eskola's scheme quite readily, and while it is similar to dynamothermal metamorphism in respect of broad causes, principles and facies, it is different in respect of the completeness of recrystallization, in the sharpness and brevity of zones and in the characteristic development of highly porphyritic rocks and sulphide ores. Also different is its close association with intense pneumatolysis and retrograde (largely hydrolytic) metamorphism. These differences are related to an environment where there was abundant water, where solutions were particularly free to migrate, and where geothermal and pressure gradients were steep. In this context the minerals of any one facies are not primarily dependent on the original composition of the rocks, but, because of the addition or subtraction of material from the parent rock, may be quite different.

The greatest single problem of the porphyroids is that of distinguishing between the earlier phases of metamorphism and the later phases of pneumatolytic and retrograde metamorphism which followed. To assist discussion the writer has adapted two terms "anamorphism" and "katamorphism" which have largely fallen out of use and which very conveniently fit the two stages of porphyroid metamorphism. Anamorphism as defined by Van Hise (1904, p. 43) is the process of rock alteration which results in the production of complex compounds from simpler ones. It is a process of dehydration and compaction usually occurring at some depth and pressure, and is the process usually referred to in the ordinary use of the word metamorphism. Katamorphism as defined by Van Hise (1904, p. 43) is the production of simple compounds from more complex ones, and includes processes of weathering and hydration at atmospheric temperatures and pressures.

Anamorphism will here be used to mean the process of progressive metamorphism, i.e., Van Hise's meaning. Katamorphism will be extended in meaning to include processes of hydration at relatively high temperatures and to include retrograde processes generally. This modification is considered reasonable since hydrothermal alteration produces sericitic and clay rocks somewhat similar to weathering products and because Van Hise's definition refers expressly to such processes of simplification of composition.

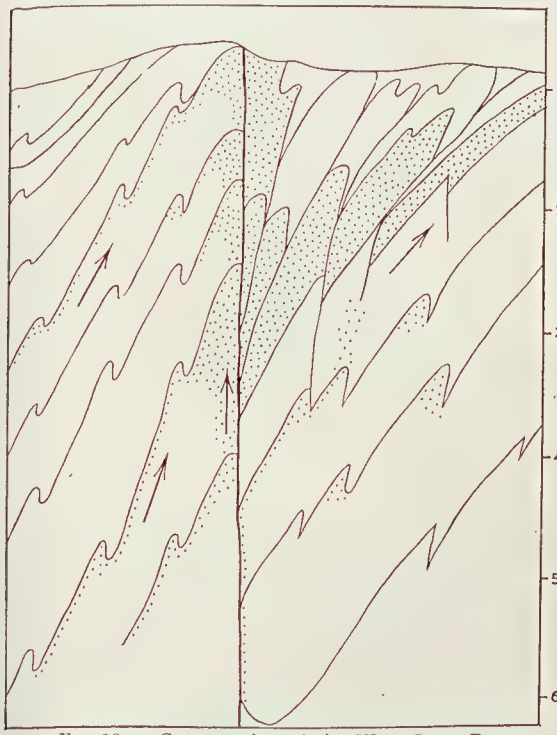

FIG. 18 *a*.—Cross section of the West Coast Range showing probable directions of flow and regions of accumulation of heated waters.

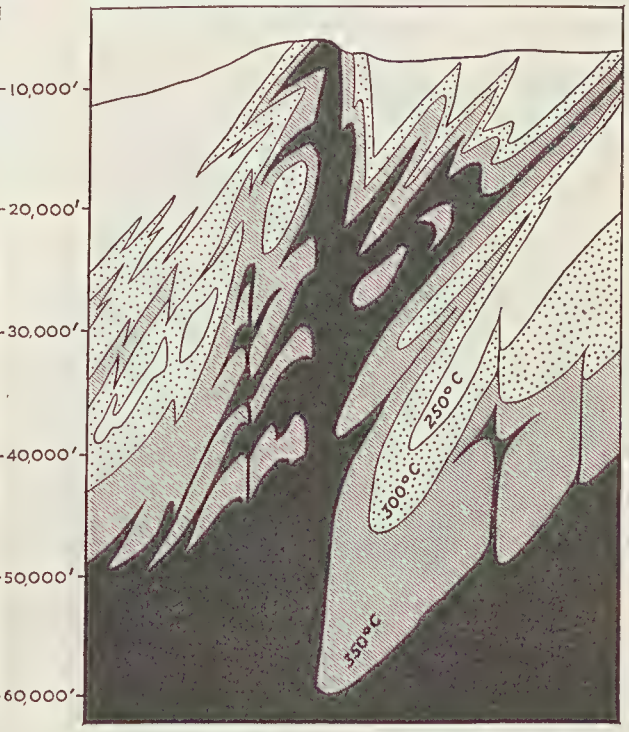

FIG. 18 *b*.—Showing general form of isogeotherms resulting from the distribution of heated waters in fig. 18 *a*.

Fluid and Heat Transfer

It is supposed that in the West Coast Range at the beginning of the porphyroid cycle of metamorphism there was an access of heat from depth along the Lyell Shear which formed a deep-rooted line of weakness in the crust (fig. 18).

Heat was transmitted by fluid transfer, i.e., through the bodily migration of intensely superheated water. Migration was fostered and controlled by shatter zones along the Lyell Shear and Linda Disturbance and by aquifers such as the Owen and Dora Conglomerates. Fuilds were further controlled by major structures such as the West Coast Range anticlinorium and travelled into anticlinal crests.

Barth (1951, p. 301) contends that migration is an old and rather obvious idea and it does not apply to metamorphic rocks in general. "By burial and orogenic pressure . . . all fissures and cavities close completely . . . Only in sheared rocks and in loosely packed sediments and their low metamorphic equivalents is permeability good enough to allow migration." The porphyroids may have been formed at relatively shallow depths: the rocks from which they were formed were particularly pervious and there was some shearing associated with their metamorphism but one would only reluctantly call the Murchison granite a low grade metamorphic product. The porphyroid rocks though in fact common are simply different from what Barth describes as "metamorphic rocks in general".

The idea of Barth (*loc. cit.*) and others that there might be no migration of fluids in deep-seated rocks is based to some extent on the assumption that the "solutions we are discussing here behave like ground water". After Gillingham's (1948) experiments it seems most improbable that water above 400°C behaves anything like ground water. Having little or no surface tension the fluid, even without volatiles and though dense, is more likely to act like a chemically active gas under very high pressures. Apart from this, cavities do not close up at the depth of formation of all granites. The tourmaline nodules of the Heemskirk granite (Waterhouse, 1916) were undoubtedly formed at the same depth as the granite was formed, yet a large proportion of them are hollow and were probably once filled with fluids. If cavities are filled with fluids at the same pressure as their surroundings there is no reason why they should close up and further, if solutions are generated by heat from hydrous minerals within the rocks, they might even attain a higher pressure than their surroundings and themselves be a primary cause of opening of fissures.

Even at great depths (10 miles or more) there is no reason why solutions should not migrate upwards any more than why basalts should not. The only difficulty is to get water down to such depths in the first instance. The continued depression of the Zeehan Syncline must have caused the deep burial of large amounts of water and the compaction of its sediments must at some stage have resulted in the migration of that water towards the Lyell Shear (fig. 18*a*). The presence of stratigraphic traps below unconformities along the flank of the growing anticlinorium must have materially assisted in the trapping of connate water and its passage to great depths.

The only problem is how deep might the rocks have been depressed before losing all their connate and combined water. This is dependent very much on the nature of the rocks concerned (the porphyroid parent rocks were essentially conglomeratic and were not "normal" sediments, *cf.* Yoder (1955, p. 509) and is largely a matter of opinion. The writer imagines that reconstitution under load would only become important in sealing a coarse aquifer of indurated pebbles, to the passage of ordinary water at depths approaching five miles, and that gas phase water would travel through pore spaces and self-created openings and shear fissures to depths of 10 miles or more. Possible directions of flow of heated fluids and the consequent warping of isogeotherms towards the surface are shown in fig. 18*b*. In view of the recorded 200°C temperatures in steam bores 1000 feet deep along wide fault zones at Wairakei, New Zealand (Steiner, 1953), the suggestion that the 400° isotherm might reach to within 10,000 feet of the surface does not seem unreasonable.

From an empiric viewpoint the penetration of the Cambrian strata by fluids even down to a molecular scale is evident everywhere. Innumerable veins of albite, quartz, and epidote indicate that rocks were permeable along fractures, and the kaolinization of the porphyry at Queenstown shows that the whole of that formation was intimately permeated by water. Where greywackes have been wholly replaced by chert, as on the track above the Comstock mine, it is absurd to say that silicon ions or silica ions cannot migrate, and where, as at the mines, there is ample evidence that quartzites have been replaced by felspar and sericite it is futile to maintain that large aluminium ions cannot be exchanged in large quantities.

The writer would not, however, advocate the diffusion of elements through crystal lattices for the porphyroids. In keeping with the broad hypothesis of gross movement of solutions in fissures and pore spaces he would advocate a detailed transmission of solutes by diffusion through immobile intergranular films of water.

Shape of Isograds

Returning to the broader picture, solutions migrating upwards established a series of pressure-temperature zones (isograds of Tilley), and as they passed through the rocks there was a mutual chemical adjustment of both rocks and solutions. In this way new mineral facies were formed and as time passed isogeotherms moved upwards so that there was formed a series of advancing waves of alteration. This idea, essentially the "front concept" of Reynolds (1946) applied in a "wet" context, is also similar to the views of Goodspeed (1952) and Backlund (1946).

As migration was controlled by fractures and sedimentary structures, the isogradal surfaces must have been most complex and the form of successive zones must have resembled a series of concentric cedar-tree laccoliths. That is in contrast to dry metamorphism where heat transport may be assumed to be by conduction and where isograds must have much simpler profiles. During an interval of time, shapes of surfaces were probably still more complex, for repeated earth movements during metamorphism must have altered the size and shape of fractures, and one must visualize a series of "cedar-trees laccoliths" superimposed on, but slightly offset from, each other. Because of periodic intense faulting and the resultant intermittent release of steam, gas pressures even to depths of miles must have varied and isograds must have fluctuated to and fro in response. Again, this is different from "dry" metamorphism where gas pressure and structural controls are much less important. The structural picture is generally complex; there must be few places in the world where everything is as simple as at Mount Lyell.

Ignoring complexities of form, and thinking only of simple shells of metamorphism, the relations between anamorphic zones must have been as follows: Individual minerals or groups of minerals may be regarded as critical and others as non-critical to specific isograds. Some, like the higher plagioclases and chlorites, might extend over wide zones, while others, like albite and epidote, were restricted to moderate temperature zones of hydrothermal alteration. Haematite was also specific, being restricted to the lowest temperature zone and pyrite was confined to the next warmer zone. This is all according to the dry concept, but because of freedom to migrate there is with porphyroid metasomatism a much smaller tendency for the original rocks to dominate the composition of the reconstituted ones. Instead, there is a strong tendency for components to migrate into zones of their optimum stability and there form concentrated zones of critical minerals. Zones thus tend to be zones composed largely of index minerals, rather than zones with index minerals, or even without index minerals as is often the case in the Scottish Highlands. Zones may, however, be diluted with less critical minerals like chlorite, and this appears to be the case of the chlorite-pyrite ore zone at Mt. Lyell.

Metamorphic Diffusion Zones

The mechanism by which "metasomatic diffusion zoning" might be effected has been treated in some detail by Korzhinsky (1948) who describes how solutions may ascend open fissures and permeate wall rocks, and how ions might further migrate by diffusing through immobile pore solutions.

This writer sees the process as one where solutions act as both collectors and precipitants. Compounds are dissolved from one zone where they are unstable and, as solutions move outwards, are precipitated in the next cooler zone. As isograds themselves move upwards so minerals like pyrite may be repeatedly leached from the rocks and precipitated, again and again, and be carried forward in a cumulative manner.

The range of conditions over which a mineral might remain stable is one factor determining the width of the zone in which it occurs. Less critical minerals may be precipitated far in advance of the isograd where they are resorbed; transport of these minerals proceeds in giant leaps. With more critical minerals, leaps are small, zones are narrow and minerals are concentrated. Where fault fissures allow easy upward travel, solutions (and isogeotherms) might migrate far ahead of their respective zone. Thus we may visualize some veining of the country rock as part of the process of anamorphism, not of late phase cooling of magmas. Such veins may be associated with all zones and isograds.

Stability ranges of minerals are not the only factors determining width of zones, for introduced chemical factors may affect equilibria. Thus reactive beds like limestones may cause the formation of new insoluble minerals like datolite at Colebrook Hill and scheelite at King Island, Tasmania, and so restrict the distribution of boron and tungsten into narrow zones. Here the freedom to migrate by diffusion in solution is determined by the affinity of the freely migrating ions for others like those of calcium which do not migrate so freely.

A discussion of the collection of water, carbon dioxide, chlorine, fluorine, &c., into a "cloud of volatiles" (Backlund, 1946) illustrates the general principle of advance of fronts and shows how the physical properties of sediments may influence width of zones. In most rocks even at great depths some water occurs either in the free state or with varying degrees of combination in clays which contain something of the order of 10 per cent water. Apart from the effects of pressure already described, the effect of heat is to reconstitute clay minerals into less hydrous species, and upward migration of heat must tend to drive the liberated water upward through any available channels. The further isogeotherms migrate, the greater the cumulative total of migrating water and its associated volatile compounds must be.

Contacts Between Zones

With increasing depth in the earth there must be everywhere, and in particular above this cloud of volatiles, some isogeotherm corresponding to the critical temperature of water. Whether or not this temperature is affected by dissolved solids as suggested by Smith (1953), and whether or not water at this temperature resembles a gas, the surface tension of water gradually diminishes with increasing temperature and normally vanishes at critical temperatures. Assuming that water in the earth similarly loses its surface tension at temperatures approaching 400°C, capillarity must cease to affect its passage through fine pores. It may further be assumed (by extrapolation from the laboratory behaviour of water) that this change of fluidity of water is in the final instance relatively sudden.

If these assumptions are correct there must, then, be some isothermal surface or narrow zone in the earth above which given rocks behave as relatively impervious to superheated water, and below which the same kind of rocks are relatively pervious to the more fluid "near gas" phase. Ignoring for the

moment the chemical activity of water at 400°C, there must be a sudden pressure (and temperature) drop across the boundary, a sudden change in the prevailing chemical equilibria, and a corresponding break in the mineral facies developed.

Alternatively, variation in the permeability of rocks may produce much the same result. Thus a wave of volatiles passing through moderately permeable strata will be held back on encountering a nearly impermeable stratum and a steep pressure gradient may develop across the contact of the two. Other factors being constant critical minerals might be deposited or resorbed at the contact and the two formations might develop separate facies. The two factors of permeability and fluidity tend to be complementary and their effects to coincide. Thus, if an impervious barrier such as the Farrell Slate or the silicified Owen Conglomerate were to impede migration, there would be an increase of fluids and pressures below the contact and temperatures would rise. This would continue until higher temperatures were reached and the barrier were resolved by the increased chemical activity of solutions. Alternatively, temperatures and pressures would rise until the barrier was resolved by explosion. The knife-edge contacts of the Owen Conglomerate at Lyell and of the hornfels "pendants" in the Darwin Granite may have been much influenced by such permeability and fluidity factors.

The passage of solutions from less permeable rocks into vast and highly permeable formations (such as the Owen Conglomerate must have been before silicification) would also be accompanied by a very sudden drop in pressure. Any broad upward migration across bedding must, as in the previous cases, result in the deposition of critical minerals at the lower contacts of such formations. Permeable beds must, however, allow the spread of relatively uniform pressures throughout their thickness and favour the development within them of one mineral facies rather than of gradation of facies. It would be possible in this interpretation for two formations like the Owen and Dora which originally had different constitutions and, presumably, different permeabilities to have developed two separate facies of metamorphism. This separation of facies along with the different original compositions of the two formations could account for their very different reactions to metamorphism, and for the deposition of ores at their contact. It seems unlikely, however, that such contacts would be sharp or transgressive like the Lyell contacts; on the contrary, relatively diffuse and conformable contacts as at Lake Dora and Red Hills would be expected.

Late Phase Metamorphism

Porphyroid metamorphism, as distinct from "dry" metamorphism is particularly characterized by its late, retrograde or katamorphic stages of pneumatolysis and hydrothermal alteration. With the cooling of a region after it has reached a peak of anamorphism there is necessarily a retreat of isograds and the possibility of retrograde metamorphism. During this phase of cooling late fracturing of the West Coast Range Anticlinorium allowed a large scale release of water over a wide area. Around these faults there was a superposition of low temperature facies on high, i.e., the kaolinization and sericitization of porphyries and granite. Migration of solutions in these processes was not guided by any regionally impelling force such as existed in the earlier advance of fronts, so one cannot properly speak of a retreat of fronts but simply of retrograde metamorphism.

The source of the water in this phase is probably the same as in the first half of the cycle. The cloud of volatiles of that early phase does not represent all of the water originally present in the rocks, but only that portion most readily detached. It seems probable that during all of the anamorphic phase, water is driven off from the rocks at all depths by rising temperatures and that this water continually migrates upwards to maintain the thermal gradient.

With rocks of fairly uniform conductivity such as occur with dry metamorphism, geothermal gradients are probably straight-line or gentle curves (fig. 19 *a*) but with fluid transfer of heat gradients are variable. The zone in which there is the greatest concentration of water is that with the greatest conductivity (fig. 19 *b*), and not only may this conductivity be some orders greater than that of dry rocks, but with time this conductive zone migrates towards the surface. This movement continues until at the peak of anamorphism the zone of conductivity reaches an optimum level as in fig. 19 *c*.

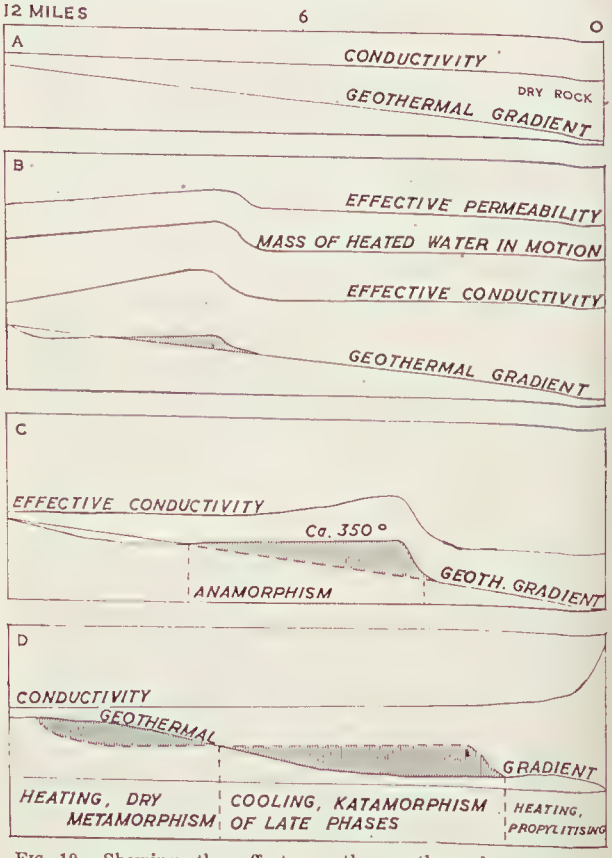

FIG. 19.—Showing the effect on the geothermal gradient of accumulating and upward migrating body of water. B, C and D represent successive stages of upward migration of isogeotherms. The dashed line in each figure indicates the state of the geothermal gradient in the previous figure.

Migration beyond this level must cause heat to be rapidly dissipated to the surface by conductivity of rocks, by eruption or by hot springs. Then although there is still a flow of heat from depth and isogeotherms at a depth of several miles are still rising and driving a little water before them, the rocks at intermediate depths may be cooling (fig. 19 *d*). It is the water driven off at this last stage which causes the late phase metamorphism of the porphyroids. This does not mean that metamorphism may not go further for isogeotherms may still rise slowly by conductivity of the rocks and if the region under consideration were depressed into the crust it would be possible to have intense dry high temperature metamorphism of rocks which had just passed through a wet porphyroid stage. There are some appearances of this having happened at Broken Hill, but not in the West Coast Range.

Mineral Facies of the Porphyroids

Reviewing in terms of metamorphic facies the Cambrian rocks which might originally have been present in the West Coast Range together with those resulting from metamorphism we have the following categories:—

(1) The original sediments and lavas. These are divisible into:

(*a*) Hydrated rocks of the weathering or N.T.P. facies (argillites and quartz arenites).

(*b*) Anhydrous or partly hydrated lavas of the sanidinite facies and fragments of similar rocks in the tuffs and greywackes.

(2) Rocks of successive stages of metamorphism.

(*a*) First katamorphic stage of the outermost hydrothermal front in which anhydrous remnants of lavas (augite and plagioclase) were hydrated at low temperatures to chlorite, sericite and kaolin rocks like those of 1(*a*).

(*b*) Anamorphic stages in which rocks of 1(*a*) and 2(*a*) were rebuilt into

(i) greenschist rocks with pyrite,

(ii) rocks of the albite epidote amphibolite facies.

(*c*) Second katamorphic stage of retrograde metamorphism in which any of the preceding rocks might be sericitized and leached of silica or quartzified. These effects tend to be irregular and localized.

(3) Vein rocks.

(*a*) Those resulting from the leaching of sediments and lavas in stage 2(*a*) and 2(*b*). These veins are composed of rocks belonging to several facies (frontal deposits of Bradley, 1956), and include quartz-haematite, pyrite, quartz-epidote and felspar veins.

(*b*) Those resulting from leaching of the metamorphic rocks during stage 2(*c*). They include sericite and chalcedonic silica veins along with tele-frontal sulphides (Bradley, 1956).

ORIGINAL SEDIMENTS AND LAVAS

Owen Conglomerate

The members of this formation are of three types, viz., argillaceous, arenaceous and conglomeratic. With the exception of some argillites in the upper part of the formation the whole is almost everywhere silicified. The shaly partings are, in general, composed of chlorite and sericite with subordinate bands of angular silt-grade quartz and with haematite in varying proportions. In the partings of the Tubicolar Sandstone on the King River the iron mineral is probably magnetite, but in most other localities haematite has been introduced along with silica.

The quartz sandstones are seen in their unsilicified state only in the Tubicolar Sandstone where they consist exclusively of sharp particles of quartz schist, quartz crystals and chert. The matrix is chlorite or sericite, and in some places limonite of secondary origin. The most striking feature of these sandstones, and this also includes the sandstone dyke rocks at Lyell, is the apparent extreme angularity due largely to grain growth of fragments less than 0·2 mm. across (plate D, figs. 18 and 19). With increasing size, particles are progressively rounded. In the purple sandstones and grits the matrix is haematite and individual quartz schist particles are very heavily powdered with haematite along grain boundaries (plate D, fig. 3).

Conglomerate beds also consist of quartz schist, quartz and chert, with varying amounts of sericitic and chalcedonic matrix. White chert fragments (5 mm.) are common only in the grits of the Tubicolar Sandstone near the Comstock Mine, and there the angular particles comprise as much as 10 per cent of the whole. It is debatable whether the chert was formed before deposition or by silicification afterwards. It is also possible that many dark siliceous hornfels pebbles in the rest of the formation represent recrystallized chert, and were originally non-siliceous rock such as slate.

Lynch Conglomerate

The Lynch Conglomerate has been described (Pt. 1, p. 221) as the stratigraphic (and less altered) equivalent of the Dora Conglomerate. The formation consists of 3000 feet of tuffaceous greywackes grading up from coarse basaltic conglomerates at the base into silty and quartzose beds immediately below the Owen Conglomerate. The uppermost member is a subgreywacke grit with small quartzite and quartz fragment pebbles set in a sericitic and chloritic matrix. The varvoid silts are composed mainly of sericite with some chlorite, clay minerals and fine quartz. The major part of the formation, and the one which is the subject of most debate, varies from slate to tuffaceous breccia. The latter consists of particles of slate, basalt and trachy-basalt with broken crystals of augite and felspar with fine-grained sericite and chlorite.

Some alteration of augite to chlorite may have preceded deposition of the sediments, but in many rocks augite is fresh and was apparently buried shortly after derivation from its source rock. This

is consistent with rapid erosion and deposition in an active tectonic environment. In general the latter metamorphism of the rocks is directly related to grain size and content of basic rock fragments, so that the most altered rocks are the basaltic breccias and the least altered are the slates.

Basic Lavas

The spilitic lavas of the Cambrian geosyncline have already been described for the region, and in particular for the occurrences at King Island and Penguin, by Scott (1951 *a* and 1952). The reader is referred to these accounts for details of those rocks. Scott (1954) has also described the deuteric stages of alteration and some features of the regional metamorphism of these rocks. The Queenstown lavas, though lacking visible pillow structures, are mineralogically spilites, and similar to Scott's examples. Plate D, fig. 5 shows a typical member of the suite whose lavas commonly have isotropic or felsitic bases with phenocrysts and/or porphyroblasts of felspar, and sometimes bear large unaltered phenocrysts of augite. Even where augite is fresh, rocks are otherwise highly altered; vesicles are filled with calcite or quartz (not chlorite) and felspars are irresolvable masses of pinite or sericite. Study of numerous samples taken from the whole area of the range show that it is impossible in any given case to be certain of the composition of the original felspar. So widespread is the sericitising epidotising and introduction of secondary felspars that commonly there are not more than the faintest relics of original minerals.

Original felspar compositions in spilites may sometimes be deduced from the textures of the rocks, but deductive conclusions can usually be debated. Thus Scott (1951 *a*, p. 131) has deduced from the occurrence of graphic intergrowths of augite and albite in the lavas at King Island that the albite was primary. The ternary system diopside-albite-anorthite (Bowen, 1928, p. 46) shows that augite and albite may form eutectics in soda rich basalts, but it also shows that anorthite and augite may form eutectics in calcic rocks.

In basalts anorthite is very rare and it seems a reasonable assumption that the albite of the graphic intergrowth described by Scott was magmatic. Bowen's figure indicates that the eutectic proportions of albite to diopside are about 20/1 while the intergrowth in Scott's (1951 *a*, p. 4) rock has proportions fairly close to the 43/47 proportions of the anorthite diopside eutectic. The graphic intergrowths could thus signify that the original felspar was anorthite and that this felspar has been replaced by albite. The fact that the pyroxene in the intergrowths is diopsidic augite might, however, completely alter the picture and all than can be concluded is that idealized experimental information on crystallization is probably inadequate for dealing with the problem, and that Scott's evidence is inconclusive.

This is typical of the spilite problem. The rocks in question probably represent the best exposed and least altered of the Tasmanian spilites, so rocks elsewhere can hardly be easier to interpret. Other empirical approaches, still using texture, are probably no more reliable than the last. The clearest case which can be made, and even this is weak, is that some rocks contain no recognizable albite, either secondary or original. Such rocks (plate D, fig. 5) may contain up to 10 per cent of highly altered felspar phenocrysts alongside unaltered augite, and it might be concluded that because albite is usually stable and appears quite fresh long after augite becomes unstable, the altered felspar was originally a calcic plagioclase.

Further empiric evidence, this time favouring an original high soda content in the lavas, is found in rock textures other than the graphic intergrowths discussed above. Some highly felspathic lavas on the Tullah Tram and on the Comstock Tram carry only small amounts of augite, perhaps 2-5 per cent, as ferromagnesian mineral, and on this score alone are probably trachy-basalts or augite-trachytes. Despite probable alterations of felspars to albite and oligoclase it seems unlikely that the rocks have ever been much different from what they are now.

Again, the general absence of ophitic or porphyritic-granular textures among the lavas indicate that they are not normal basalts. This is the more suggestive since basalts with relatively low proportions of augite might be expected to be ophitic rather than to have the simple porphyritic habits of the Cambrian lavas (Clark, 1952).

Among the original rocks of the region there are, apart from spilites, possible hornblende andesites. One from the tuffs on Lynch Creek contains hornblende which, though altered, appears to be an original mineral. In the vicinity some actinolite crystals occur, but these are acicular and clearly have grown on augite. While these cannot readily be confused with the idiocrysts of very decomposed hornblende occurring in the tuff the hornblende may still be secondary. This example along with a similar rock described by Scott (1954, p. 140) and a number of indisputed hornblende lavas recently discovered by Banks (personal communication) indicate a widespread but probably minor andesitic vulcanism in the region.

Fortunately, little depends on knowing the precise composition of the original lavas. Not only do deuteric and later metasomatic processes overlap and resemble each other, but from the ubiquity of the association it seems that the processes are related, and can be treated together. It is believed that most rocks originally belonged to a calc-basalt—trachy-basalt—trachyte-suite like those of present day oceanic environments, and they included sub-aerial as well as submarine representatives. It is believed also that the extrusion of the lavas was probably controlled by faulting movements related to those which later gave rise to the Dundas and West Coast Range geanticlines, and which controlled the upward passage of metasomatizing sodic solutions. It seems probable that these solutions were most active during the Tabberabberan orogeny, but they may also have had some effect during the Tyennan orogeny, and they may have been effective in causing contemporaneous spilitising of the lavas.

ALTERED ROCKS

The Anamorphic Sequence

Of all the rocks, the basic lavas are the most sensitive to the earliest changes of pressure and temperature. This is partly because of their mixed composition and partly because their felspars and pyroxenes are metastable. These contrast with hydrous minerals and quartz of the stable slates and quartzites. Attention will be directed first to the stages of alteration of lavas and tuffaceous greywackes.

Stage I. Calcic felspars are sericitised but there is little other change except that the silica and lime freed in this process find their way into vesicles of lavas and pervade the greywacke country rock. The latter is sometimes silicified along pervious breccia bands or veined with calcite and lavas are often completely silicified (Scott, 1954). Most of these effects, which could be the result of either deuteric or imposed metamorphism, require only low temperatures and the introduction of water and carbon dioxide.

Stage II. In the groundmass of the lavas, in the matrix of the tuffs, and not necessarily associated with original felspars, small clusters of red felspar are formed and red felspar veins cut the rock. Both felspars have a refractive indices np = 1·51, ng = 1·54 (Ab_{95} An_5). In this and all the subsequent changes of plagioclase Eskola's spilite reaction is probably important. The reaction reads

$$\underset{1\ \text{ANORTHITE}}{CaAl_2Si_2O_8} + \underset{1\ \text{SOD. CARB.}}{Na_2CO_3} + \underset{4\ \text{SILICA}}{4SiO_2} = \underset{2\ \text{ALBITE}}{2NaAlSi_3O_8} + \underset{1\ \text{CALCITE}}{CaCO_3}$$

Eskola (see Barth, 1951, p. 286) has demonstrated that this reaction is reversible with pressure so one might conclude that the albitising, whether deuteric or imposed, occured at relatively low pressures. If solutions were juvenile this low pressure need not signify very shallow depth but merely that solutions had free egress to regions of low pressure. However hypothetical the source of these solutions might be, there is no question that silica, sodium and carbon dioxide were added, and it will be assumed for the present that there were solutions of this kind.

Stage III a. Solutions and reactions similar to the last, but with higher temperatures, caused the formation of many minerals of the lavas. Prehnite, which occasionally fills vesicles in the Rosebery Lavas and the King Island Lavas (Scott, 1951 *a*) may be formed along with albite, thus:

$$\underset{4\ \text{ANORTHITE}}{4CaAl_2Si_2O_8} + \underset{2\ \text{SOD. CARB.}}{2Na_2CO_3} + \underset{6\ \text{SILICA}}{6SiO_2} + \underset{2\ \text{ENSTATITE}}{2(MgFe)SiO_3} + \underset{3\ \text{WATER}}{3H_2O} \geqslant \underset{4\ \text{ALBITE}}{4NaAlSi_3O_8} + \underset{2\ \text{CALCITE}}{2CaCO_3} + \underset{1\ \text{PREHNITE}}{Ca_2Al_2Si_3O_{10}(OH)_2} + \underset{1\ \text{AMESITE}}{H_4(MgFe)_2Al_2SiO_9}$$

The amesite molecule may combine with serpentine coming from hydration of pyroxene to form chlorite and this would explain the occurrence of chlorite alongside prehnite in vesicles. It is characteristic of this stage that augite is broken down.

Stage III b. Probably at slightly higher temperatures or pressures there occurs a third reaction which introduces hydrogrossular.

$$\underset{4\ \text{ANORTHITE}}{4CaAl_2Si_2O_8} + \underset{2\ \text{SOD. CARB.}}{2Na_2CO_3} + \underset{4\ \text{WATER}}{4H_2O} + \underset{2\ \text{ENSTATITE}}{2(MgFe)SiO_3} + \underset{5\ \text{SILICA}}{5SiO_2} \geqslant \underset{4\ \text{ALBITE}}{4NaAlSi_3O_8} + \underset{\text{CALCITE}}{CaCO_3} + \underset{\text{CARBON DIOXIDE}}{CO_2} + \underset{\text{HYDROGROSSULAR}}{Ca_3Al_2Si_2O_8(OH)_4} + \underset{\text{AMESITE}}{H_4(MgFe)_2Al_2SiO_9}$$

The close similarity between the last two reactions suggest that products of each should be found in close proximity. This is not only so among the Tasmanian spilites (Scott, *loc. cit.*) but is true among the pyroxenites and spilites of Dun Mountain in New Zealand where great veins of each mineral are found. The association of spilite and pyroxenite with hydrogrossular is probably general, although many workers have given descriptions of hydrogrossular without recognizing it as such. This is obviously the nature of the so-called "glass" which invades and lines vesicles in Teall's (1899, p. 86) example of Lower Palaeozoic spilites in the Southern Uplands, and in Stamp and Woolridge's (1923, p. 38) example. Ballsillie (1932, p. 109), at Ballantrae, also recognizes "vitreous matter" which "gathers into vesicles" and describes a similar material veining the neighbouring serpentine as having R I 1·728, and as being "like a variety of garnet". See also Scott (1951 *a*). An important association of the hydrogrossular on Dun Mountain is that it forms the gangue mineral of chalcopyrite lodes (Bell *et al*, 1911, p. 60, and Grange, 1927, p. 160). Elsewhere in New Zealand it occurs in the association calcite, tremolite, chlorite and prehnite (Turner, 1935) which also occurs in Tasmania. It very clearly falls into a moderate temperature zone, perhaps about 200°C, and belongs to the greenschist facies. Hydrogrossularising is an important process associated with albitising.

Stage IV. Recrystallization of lavas proceeds rapidly with the final resorption of the original calcic felspars and the formation of new oligoclase-rich rocks. Important changes here are epidotising and formation of actinolite, but there is not yet the development of biotite or garnet which are commonly present in similar rocks (Turner and Verhoogen, 1951, p. 469). At this stage the rocks of Lynch Creek and East Queen River begin to grow minute stringers of quartz and epidote, and under the microscope small grains of quartz are recognizable as entities for the first time. Under the microscope epidote is scattered throughout the slides and grouped in clusters of granules around that which was previously lime-rich felspar or vesicle fillings. Here such augite as had till now escaped chloritising becomes altered to fine needles or fibres of actinolite, and veins of tremolite cut the rocks. Occurrences of tremolite vary from veins some feet wide on Lynch Creek down to small isolated needles, and probably result from a reorganization of the material of the chlorite and calcite. From this point on there is a robbing of the rock of carbon dioxide, and a general dehydration, and calcite disappears. Although this has not been observed by the writer, reorganization of prehnite and hydrogrossular probably occurs with the first appearance of epidote, these two minerals being made over to epidote.

Stage V. In the succeeding stage of metamorphism the rocks are substantially altered to felspar porphyries when the whole rock (e.g., Red Hills and on the Mackintosh River at Tullah) is made over to oligoclase Ab_9 An_1. Throughout all of the previous stages some chlorite has been present, but in diminishing amounts, and at the optimum of this stage it is usually about 4 per cent of the rock and the only ferromagnesian mineral. Epidote also disappears at this stage and its lime presumably goes into the new oligoclase felspar. Barth's (1951, p. 284) graph gives a temperature of under 300° for this reaction. These rocks are true syenites and it is small wonder that Twelvetrees gave them this name. As it is quite impossible to distinguish some of these from coarse trachytes under the microscope the only evidence of their origin must, perhaps, always be field observation of volcanic or sedimentary structure. It is at this stage that biotite first appears in faded wisps among the felspars. Always the minerals look as though they had been weathered and the felspars, no matter how new, are powdered and pitted with sericite or kaolin. The only index of newness now lies in the degree of idiomorphism of felspars or in the relict outlines which felspars occasionally leave behind them.

Stage VI. The blotchy syenites of the Murchison River provide the type of the next stage of alteration. Here the rock is coarse grained with crystals of red and pink felspar from 2-5 mms. across and with biotite and dark-green chlorite, obvious even in hand specimens. The felspar is now only in part oligoclase, and is 50 per cent or more of orthoclase. There is usually little twinning or zoning of the plagioclase and felspars are highly sericitized.

Stage VII. The final stage is represented by the granites of the Murchison River and Mount Darwin Plateau. Taking the latter occurrences first, the felspar is orthoclase, and quartz is very variable, from 10-40 per cent. Felspars are, on the whole, sericitized and are hypidiomorphic. The quarz is most interesting; it is interstitial and often occurs in tiny grains just as it might in veins or in a quartzite; groups are made up of individuals of differing sizes and it appears that the granite approaches normality with the growth of these crystals into larger compound units (plate B, fig. 6). The largest and most nearly normal of these crystals are conspicuously shadowy in their extinctions as though their constituent grains had been badly assembled.

The ferromagnesian minerals, biotite 1 per cent and chlorite 3 per cent, are also curious. The chlorite is so widely disseminated through the rock as to give it a greenish hue, but is inconspicuous in thin section. Some chlorite, which occurs in stringers, does not appear to be an alteration product of pre-existing minerals, but the biotite of the rock appears, because of its highly idiomorphic character, to be an alteration product of the chlorite. Biotite is very sparse indeed, so sparse that it appears in none of the writer's thin slices. It appears in the field, however, as hexagonal crystals some 3 mms. high and wide. Barth (1951, p. 337) claims that such associations belong to the epidote amphibolite facies and choosing antigorite to represent chlorite he suggests the following reaction occurs at about 250°.

$$\underset{\text{ANTIGORITE}}{Mg_3Si_2O_5(OH)_4} + \underset{\text{ORTHOCLASE}}{KAlSi_3O_8} \rightleftharpoons \underset{\text{BIOTITE}}{KMg_3AlSi_3O_{10}(OH)_2} + \underset{\text{2QUARTZ}}{2SiO_2} + \underset{\text{WATER}}{H_2O}$$

This provides a possible source for a small part of the granular quartz of the rock but the temperature suggested by Barth seems very low. Were these rocks schistose or hybrid gneissose types this low temperature would cause no surprise, but in interpreting the rocks in facies terms we now have to accept completely crystalline rocks as low temperature derivatives. The most common rock contains one-inch crystals of pink orthoclase set in a coarse groundmass of orthoclase, quartz and chlorite and though broadly stratified it is an undoubted granite.

That is a very broad picture of the granite which is very varied and which, in some bands, is fine grained or approaching graphic in texture, and which in some bands has both biotite and muscovite mica. Here again it may bear pegmatitic veins of chlorite with pyrite or irregular stringers (six inches wide) of magnetite, both clearly part of the rock and originating more or less *in situ.*

The Murchison River granite is similar to the Darwin granite except that chlorite is very minor, and biotite is more prominent. Interstitial quartz is present here in large crystals rather than granules, but shadowy extinction is general. This granite has one distinctive feature, viz., the presence, along the east bank of the gorge, of an aplitic phase paralleling the contact with the haematised conglomerate. The rock (plate D, fig. 6), is a typical aplite with interlocking grains of quartz and felspar in proportions of 40/60, and the felspar is orthoclase and orthoclase perthite in equal proportions.

Summary

The sequence of stages so far described is selective, but in the field there is an overlap of all stages and the sequence is thought to be representative. At first there were hydrating processes involving the formation of sericite and chlorite, and these were paralleled and followed by anamorphic reactions of building of felspars, biotite and tremolite. While the materials of different reactions were often used several times to build up new minerals, the alteration of basalts to potash granites necessarily involved the addition or subtraction of materials. In the first sericitising stage there was an influx of alumina and/or elimination of silica (*cf.* Turner and Verhoogen, 1951, p. 483). In the next three stages where albite was formed and augite and then chlorite eliminated there was an influx of soda and silica with an influx of lime, magnesia, and iron. In the Murchison syenite stage there was a progressive elimination of soda and water and an increase in potash. These are all absolute changes where individual pebbles, or beds of rock, can be said to have lost original minerals and gained others of quite different compositions.

The incoming of quartz in the potash granites probably represents a different and relative kind of change and may not mean that there has been an addition of silica to the syenites. The elimination of oligoclase and its replacement by quartz could readily mean that both soda and alumina have been removed and excess silica left behind. This kind of reaction would be different from the preceding examples also in that it must involve some change in volume.

Volume Changes in Metasomatism

The porphyroids, more than other rocks, demonstrate that it is equal volumes and not equal weights of minerals which replace each other. This principle, enlarged on by Turner and Verhoogen (1951, p. 483), may be critically important in determining reaction in rocks under great pressures or where other circumstances preclude migration of materials. In porphyroid metasomatism the principle may, however, be relatively unimportant in determining the course of reactions and may have a different kind of significance. For example, if replacement of silicate rocks can be demonstrated to have occurred there must often have been migration of material to make up for the gain or loss of weight per unit volume. This is made clear by Lindgren (1924, p. 507) in relation to the iron silica and sulphur replacements at the contact zone at Bingham, and obviously the principle must apply to replaced silicate rocks also.

Nevertheless, there are reasons for supposing that there may have been some appreciable volume changes in porphyroid metasomatism. The aplite veins of the Murchison River granite are in two instances ptygmatically folded, a kind of folding which signifies to the writer that there has been a shrinkage of the rock enveloping the aplites. The shrinkage mechanism canot be unequivocally demonstrated by the examples on the Murchison River, but suitable cases can be taken from photographs of ptygmatic folds in a similar porphyroid granite of Finland (Sederholm, 1926, figs. 30-40). Useful examples showing two or more intersecting and ptygmatically folded dykes (fig. 20) are thought to be fully explicable in the following terms.

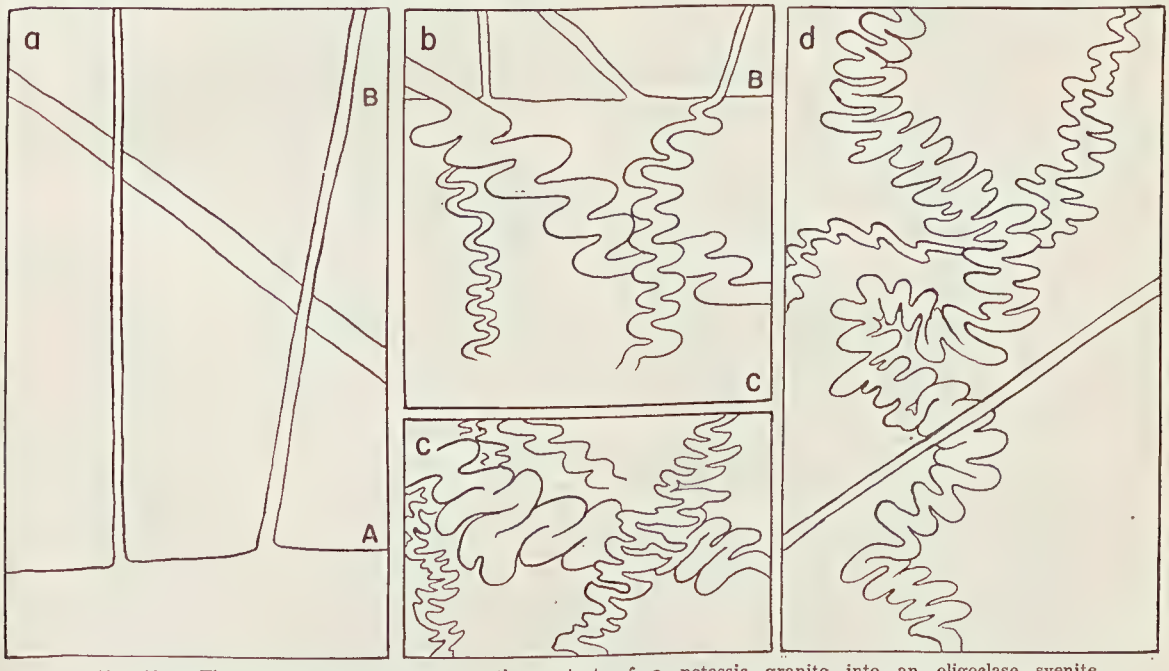

FIG. 20 *a*.—Three aplite dykes rise from the contact of a potassic granite into an oligoclase syenite. The potash front advances from a Level A to a higher level B and partial removal of silica and alumina decrease the volume of the altered rock in the proportion A-B to B-C fig. 20 *b*. The aplite *dyke* which has the same composition as the potash granite is unaltered and retains its volume, but it adjusts itself to its new vertical dimension by folding (20 *b* and *c*). The radius of folds in any dyke is related to the thickness of the dyke (20 *c*). When a dyke is tightly folded its effective thickness increases and it folds on a larger radius (fig. 20 *d*). (Based on Sederholm 1926, figs. 30-40.)

In the first instance (fig. 20 *a*), aplite veins run ahead of their respective front into the overlying zone. When the potash granite moves up and takes the place of the sodic syenite it appears that there is a reduction of the volume of the syenite. Dykes having the same composition as the granite are, however, unaffected by this change and, retaining their own volumes are folded in the manner shown (fig. 20 *b* and *c*).

For the Murchison granite this kind of reduction in volume coincides with the elimination of oligoclase and the incoming of quartz. This implies that soda and alumina have migrated in a wave beginning at this horizon.

The upper limit of the wave of aluminium metasomatism is well defined at several points in the range by the sericitizing and felspathising of quartzites. At the Lyell contact the replacement of

quartz by sericite clearly requires the addition of alumina and alkali, and if it is assumed that all of the quartz replaced has gone to sericite, there must have been an increase in volume by about 100 per cent. The intense local contortions of the sandstone dykes at Lyell suggest that there may have been some expansion and consequent readjustment of the schist along the contact. The schist must under these circumstances have tended to be squeezed into anticlinal crests or other zones of relief. This might explain the "mashing" which seems common at similar contacts elsewhere (Van Hise, 1897, p. 239) and the common difficulty in tracing beds across contacts. Apart from contortion there is no evidence of great increase in volume at contacts and it seems that silica must have been dissolved in large amounts to make way for the incoming sericite. The silica, apart from that required to make up sericite, has apparently passed upwards into the Owen Conglomerate. Felspathising of the quartzites, as at Darwin Spur, must also have involved the introduction of alumina and the removal of silica in the same way.

Retrograde Metamorphism

By the time late hydrothermal injection of the porphyroids commenced, the permeability which had directed earlier solutions along stratification planes had disappeared. Sericitising, chloritising and kaolinising were thus centred around broad crush zones like the Linda Disturbance, or late faults such as the N.E. tensional faults.

Late Sericitising and the Origin of Quartz Porphyries.

The term sericite, as generally applied to the micaceous alteration products of alkali felspars, appears to be conventional in that in many cases where sericite is used the mineral concerned is probably the soda mica, paragonite, and not the potash mineral. Yoder and Eugster (1955, p. 255) define sericite as "a field term used to describe any fine-grained white mica" and state, "The white micas include muscovite and paragonite". "Sericite" will be used in this vague but customary sense in this account.

In view of the richness of the porphyroids in soda it must be expected that in some cases the hydration products of felspars will include paragonite. Experiments by Morey and Chen (1955, p. 999) suggest, however, that in the breakdown of albite the potash impurities of the mineral tend to remain behind as muscovite, while sodium compounds pass into solution. Perhaps this explains a small part of the relatively high concentration of potash in the Lyell schists near Queenstown, and it suggests that in some places sericitising may be merely a process of leaching of soda. At still other places it seems probable that sericitising involves very little potash and the process is one of paragonitising.

The sericitising of the Owen Conglomerate at Lyell is, in fact, different from either of these processes, for it is clearly a process of introduction of potash. Analyses of the specimens of plate A by Mr. Ritchie (D.S.I.R., New Zealand) show the following variations of alkalies across the contact zone of the Owen Conglomerate. Specimen 1 (plate A, fig. 3) is taken from the conglomerate at the stage of metamorphism where the quartz begins to lose its lustre and has an Na_2O content of 0·1%, and a potash content of 1·6%. Less than two inches away, where the rock is the sericite schist of plate A, fig. 6, the corresponding contents are Na_2O 0·4% and K_2O 4·2%. There has been an addition of potash to the quartzites to form muscovite.

The coarser quartz porphyries are non-schistose analogues of the quartz-sericite schists, and the common occurrence of orthoclase porphyroblasts in them indicates that potash was added to the rocks during their formation. Since the potash causing these alterations was introduced during the cooling phase of metamorphism it seems probable that there are two sericitising phenomena associated with porphyroid metasomatism. In the stage of advancing fronts sericitising probably involves leaching of soda, and in the second or late phase, sericitising involves an introduction of potash. The source of the potash in the second case is attributed by the writer to the leaching by late phase solutions of still deeper seated rocks, and it is supposed that sericitised potash granite occurs at a depth less than 5000 feet below the present quartz porphyries. Without this explanation the presence of a clearly defined high temperature zone of introduction of potash (i.e., in the granites) is at variance with the introduction in the same area of potash in low temperature sericite (muscovite) schists. In the West Coast Range all felspathic rocks are sericitised in some degree; in general the felspar porphyries have suffered least, and progressing through rocks with increasing amounts of quartz to quartz porphyries alteration becomes more intense. In the quartz porphyries hydration has sometimes proceeded to the extreme where felspars have been wholly leached of alkalies and reduced to kaolin, as for example in the area within a forty chains radius of Queenstown.

During complete sericitising of alkali felspars some 20 per cent by weight of the original mineral is removed as silica in solution. Some of the silica so released from the porphyroids probably found its way through fault fissures and emerged at the surface in hot siliceous springs. Much silica was, however, precipitated in the aquifer of the Owen Conglomerate (Bradley, 1954, p. 231) and in veins. Where solutions can migrate so freely, hydration might easily go to completion and felspars be reduced to kaolin; but this seems to have happened only on the Linda Disturbance at Queenstown. It seems instead that there was usually some structural restriction on transport and that at times there was no appreciable movement of solutions. The rock and the immobile solutions constituted a closed system in which composition stayed constant and where it was possible for an equilibrium to be set up between quartz, felspar, sericite, water, potash and soda. In particular, silica accumulated until it reached saturation point and then crystallized *in situ* as quartz. Most workers would agree that this may be the mode of origin of quartz in sericite schists, but that is not all that is in-

tended here. The silica in the porphyroids very often crystallized at many centres within the sericitised felspar porphyries as idioblastic crystals, and so formed quartz felspar porphyries and quartz porphyries. This idea has been proposed in principle by several workers who have claimed that quartz phenocrysts may be porphyroblasts. Thus Scott (1954, p. 140 and plate 4, figs. 1 and 2), Stanton (1955, p. 606) and Goodspeed (1937) have all described the pimply protuberances around large quartz crystals as growth structures and have called the crystals porphyroblasts.

The main contribution of this work is to establish that this process of quartz porphyritising may be of regional extent, and further that it may be the result of retrograde metamorphism. This principle of sericitising and quartz enrichment applies equally to any felspathic rocks whether lava or greywacke, and whether or not they have been metamorphosed to felspar porphyries. The regional quartz porphyries in Tasmania include all these types, but since the felspar porphyries provide the most favourable raw material for such changes and naturally occur in the most favourable sites for late injection, most quartz porphyries are altered felspar porphyries. At second hand they are altered sediments and lavas and there is even some case for supposing that ultrabasic rocks near Dundas (Elliston, 1954, p. 173) may also be secondarily altered to quartz porphyry.

Even on the regional scale this general idea is not new for it was expressed long ago by Wadsworth (1887, p. 68) who stated "part of the corroded and fissured quartz penetrated by the groundmass in quartz porphyry . . . has been formed in the rock as an alteration product subsequent to the solidification of the rock, and is due to the migration and aggregation of the silica set free during the alteration of the rock".

The proof of these assertions must usually rest in the final instance on the field demonstration that the porphyries have the structure of sediments (Bradley, 1954) rather than on microscopy, but there are numerous confirmatory lines of evidence, and some details of the crystallization of quartz are convincing.

Without listing the deficiencies of the magmatic theory on the following scores this thesis explains the presence of quartz phenocrysts in rocks ranging from sediments through granitoid rocks and augitic lavas in Tasmania to gabbros in Minnesota (Wadsworth, *loc. cit.*), and explains the presence of so-called quartz xenocrysts in the olivine basalts (Exeter Traps), along with quartz porphyry conglomerates on the margin of the Dartmoor Granite (Tidmarsh, 1932, p. 730).

This thesis of origin of quartz porphyries implies that similar regional porphyries in other parts of the world should also be associated with intense sericitising There are, it seems, very few quartz porphyries which are not highly sericitised; there are many in which the groundmass consists exclusively of sericite, and more than a few in which the groundmass is highly kaolinised.

In general, regional quartz porphyries are characteristic rocks, perhaps the most characteristic (next to pegmatites) of intensely pneumatolysed terrains. When they occur as veins as at Mount Bischoff, Tasmania, the quartz porphyries may have many of the characters of pegmatites and bear cassiterite and topaz.

Quartz Felspar Porphyry

The distinction made by previous Tasmanian workers between felspar porphyries, quartz felspar porphyries and quartz porphyries is a useful one in that it denotes the degree of alteration of the rocks. Under the microscope the first appearance of free silica in the rocks is in the form of an indeterminate granulation of the groundmass between the felspar crystals. The next stage shows some of these granules growing together in very irregular quartz porphyroblasts, 0·1 mm. across. At this stage there are few, if any, crystals showing resorption cavities or inclusions of any kind. In the next stage where quartzes are visible in hand specimens and are some 1·0 mm. across, the rock under the microscope is the ill-defined quartz porphyry or quartz felspar porphyry of convention; it has up to 5 per cent of quartz, but the felspars are still readily recognizable as felspars—this is the "quartz felspar porphyry" of this work.

Quartz Porphyry

Beyond this quartz felspar porphyry stage the groundmass of the rock becomes vague and hornfelsic looking; it is made up of many small irregular quartz grains, sericite flakes and specks of kaolin which may obscure the felspars completely. The final type of quartz porphyry, in which quartzes are some 5 mm. across and from 5-20 per cent of the rock, is what the writer would describe as the ideal quartz porphyry. This consists of quartz, often resorbed, set in a groundmass almost exclusively of sericite, but with perhaps a little chlorite. In hand specimen the rock is often a dark blood-red from specks of haematite scattered through it, but in thin section these are not obvious among the kaolin and sericite. This colouring tends to be distinctive of the more quartzose types, for the more felspathic frequently owe their colouring to chlorite and are often green. In the extreme type of quartz porphyry, flakes of sericite are commonly arranged in a rectangular pattern which suggests that they have been formed on cleavage planes of felspar, but this is probably not the case. This texture is the antithesis of the schistosity of the nearby and related sericite schists, and the cuboid ordering of the flakes seems to be the result of growth and adaptation in a strain-free environment. In the absence of strain, orthoclase grows in these rocks as pimply porphyroblasts (plate B, fig. 3), but the felspar usually remains less than 10 per cent of the rock and is prominent only in the Mount Bischoff porphyry. It seems from the degree of sericitisation of these felspars that newly formed orthoclase is very readily reconverted to sericite.

Shadowy Extinction

The quartzes of all the porphyries tend to have the shadowy extinction which is usually attributed to strain, and commonly have an irregular or pimply outline (plate C, fig. 5). Shadowy extinc-

tion in these rocks is, however, not the result of strain but of parallel or subparallel growth of quartz crystals. This can be seen in some specimens like plate C, fig. 1, which shows a large number of small quartz hexagons disposed side by side, but not quite parallel to each other. This kind of section can be duplicated very readily by cutting a section through the encrusting quartz crystals lining the inside of geodes, and the same structure is common in much fine-grained quartz from veins. It might be claimed that the section is, in fact, from a small vugh in the porphyries and that it has no other significance. In the porphyries there is, however, transition from the figured specimen through every gradation of disjunctive shadowiness to non-shadowy quartz. Disjunctive shadowiness is that where a large crystal is made up of a large number of discrete individuals, each of which has its own extinction and its own optic orientation (*cf.* Goodspeed, 1937). Orientations change abruptly from one crystal to the next, but the change is progressive across the larger compound grain and so extinction shadows move in one direction and in jerks. Even non-shadowy quartz has some submicroscopic disorientation, for it is common for the quartzes of the porphyries and of the potash granites to be biaxial and to have 2E as high as 10°. Although this is usually taken to mean that crystals have been strained the aggregate of plate C, fig. 1 would show a biaxial character if one used condenser and objective large enough to embrace all of the crystals at once. Conversely, the biaxial character of ordinary crystals to ordinary lenses could be due to the presence of submicroscopic crystals progressively disoriented from each other. If we follow this argument far enough down the scale of size we should arrive at disoriented unit cells which would represent a bent crystal and which would be a strained crystal of a kind. It happens, however, that crystals are not usually bent in earth movement but are usually sheared on varied planes and strain shadowiness is random. Such crystals which are common in the sheared quartz sericite schists show an irregular pattern of shadowiness and rarely give a clear biaxial figure. These shadows are of the type described by Hietanen (1938, figs. 4 and 13) from highly sheared quartzites. Neither they nor the Böhm lamellae described by Hietanen are quite the same as the disjunctive shadows of the porphyry quartzes.

Quartz Sericite Schists

Quartz sericite schists are strictly limited to narrow zones of intense faulting and at Lyell are most conveniently seen about half a mile from the Gap on the Queenstown road. The rock (plate A, fig. 6) is very similar to the quartz porphyries except that the sericite here is schistose and generally wraps around quartz crystals. In some cases sericite runs straight into the quartz grains as if the latter had formed after schisting and these same quartzes often have pimply margins. Quartz crystals, which commonly form less than 20 per cent of the rock, vary in shape and size; e.g., grains may be broken (plate D, fig. 4), equidimensional and round, bear resorption cavities, or may be irregular or elongate. Only the larger elongate crystals are aligned with the schistosity and they show no obvious optical orientation.

Shadowy extinction is general in these quartzes, but by contrast with the porphyry quartzes the movement of shadows is smooth in detail and is in random directions. From the distribution of fractures in the quartz of plate D, fig. 4 it may be concluded that breaking strains were unevenly distributed through that crystal. It seems probable, therefore, that in other crystals stressed to a point just short of breaking any residual strains would have distributions similar to that of the cracks. One should, therefore, expect extinction shadows at any one time to form a dark, irregular and rhomboidal grating which would expand or contract smoothly with the rotation of the microscope stage. This kind of strain shadow is common among the quartzes of the quartz sericite schists and will in a later paragraph be shown to have interesting implications.

Chloritization

Chloritization, like the previous processes, may be a late process as well as an early one of advancing fronts, and the late process is concentrated in shatter zones. Chloritized rocks resulting from this process are located around the intersection of shatter zones with lava breccias and conglomerates which escaped the earlier metamorphism, e.g., in the area within a twenty-chain radius of the Queenstown Smelters. Where Conglomerate Creek cuts the rocks twenty chains above the road bridge, the clays are just sufficiently strong to stand as outcrops in the stream bed, and here the sedimentary structure of a conglomerate shows up clearly, and relics of original individual felspars show up as paler green rectangles of sericitic clay in the darker green groundmass. Smears of the green material on a slide convey no more idea of its nature than does a smear of the clays of the kaolinised rocks. To convey this indeterminacy the term "earthy chlorite" is apt, but it is probable that the material is often more than 50 per cent kaolin and 25 per cent sericite. It is important to maintain the theoretical distinction between this material and the early or frontal chlorite sericite schists of the mine open cut, and fortunately there is a practical distinction also. The frontal chlorites are relatively tough and fissile and bear conspicuous disseminations of pyrite, whereas the late chlorite is massive clay without trace of sulphides. It might be tentatively supposed that the chlorite fraction of these rocks is the same as that of the late chalcopyrite veins which occur in the open cut. In the latter case sections can be made and the mineral determined as pennine.

METASOMATISM

General

Many accounts of metasomatism consider that exchange of material is restricted to a small bulk of mobile elements whose small ions are capable of passing through the interspaces of large ions such as those of oxygen and silicon. Read and Barth (1951, p. 313), who favour this view, see the proportion and position of oxygen ions as relatively unchanging during metamorphism, while

others like Poldevaart (1953, p. 501) assume where possible that the number of $(Si, Al)O_4$ tetrahedra in a silicate rock remains constant, and that changes are restricted to other constituents. Poldevaart recognizes, however, that in replacement ore bodies silica tetrahedra may be removed.

Just how ionic replacement is effected in metasomatism is understood no better than comparable ionic processes of crystallization and reaction in acid silicate melts, but one might agree with Lindgren (1933, p. 91) that "it is a process of practically simultaneous capillary solution and deposition", and with Poldevaart (1953, p. 481) that "it takes place in the presence of a fluid phase-water". Some system of particle-by-particle replacement seems to be the only possible mechanism which can explain pseudomorphic replacements of carbonate or silicate by sulphides. In these cases there are no complications of solid solution, or of exchanging small ions, &c., and it can only be concluded that there has been a wholesale change of material and a wholesale transport through what now seems to be solid rock. The scale of such phenomena is not always small, for many millions of tons of sulphides and silica must have been exchanged in the formation of ore bodies at Lyell.

Thus, while the principle that there should be the least possible migration of material accords with the economy of nature and is accepted here as a basic principle, it is clear that solid diffusion is not always the most effective transport mechanism. In the porphyroids transport in solution through fissures, between particles, and along crystal boundaries was probably more important than intra-lattice diffusion. The idea of a continuous system of fault fissures (arteries) of pore spaces (capillaries) and intergranular films (diffusional membranes) is as familiar as our own blood systems. In both systems transport may be effected by diffusion and bulk movement in large channels, and by diffusion alone in the smaller.

As distinct from the movement of cold water in surficial hydrological processes, transport in the porphyroids was by water at temperatures ranging up to 400°C, and it is considered that in this state water would in time penetrate the pores of most unmetamorphosed rocks. Other factors favouring transport of solutions in the porphyroids of the West Coast Range were the conglomeratic nature of the bulk of the sediments, the shallow depth at which metamorphism occurred, and the intense shearing of the less permeable strata.

To give some order of sizes involved in the transfusion system of the porphyroids it is suggested that, except for the slate rocks, solutions might reach through pore spaces to within six inches of every given point. Transport of ions in these solutions was primarily by diffusion but was at times by bulk movement also. Transport for distances less than six inches (usually less than two inches) is regarded as having occurred by diffusion through intergranular films.

Intergranular Films

The operation of films is best illustrated by reference to the growth of quartz porphyroblasts. In fig 21 *a* it is supposed that two quartz crystals *A* and *B* are suspended in water. This has some suitable flux dissolved in it and temperatures and confining pressure are such that water dissolves silica in appreciable amounts (Gillingham, 1948, p. 242). As crystal *A* is smaller than *B* it has a larger surface weight ratio, and because of this it may have a relatively larger number of unsatisfied bonds of its crystal lattice exposed at its surface, and may have a relatively higher free energy, than crystal *B*. The result of this is that the smaller crystal has, weight for weight, a lower heat of solution than the larger and will dissolve in the water more readily. If the water of our example becomes barely saturated with silica respective to the larger crystal, it must still be unsaturated for the smaller, which must dissolve away. Any resultant increase in the saturation of the solution must, however, cause the large crystal to grow and it will ultimately "absorb" the smaller (Turner and Verhoogen, 1951, p. 396).

If the width of the channel of fig. 21 *a* is decreased almost to vanishing point (fig. 21*b*) the same transfer process will operate more and more readily as the distance of travel of ions decreases until the stage of fig. 21 *c* is reached, where the lattices of the two crystals are nearly touching. The forms of adjacent surfaces are idealised in the figure for it is probable that crystal lattices will be strained and distorted at such margins. Despite this it is thought that the basic principle is probably valid and that there may be some irregular space between crystals which would accommodate ions of varying sizes. Sizes of spaces might vary widely depending on the kinds of crystal and lattice involved. Parallel flakes of mica or chlorite such has occur in a slate or schist would probably allow very little room and the same may apply to oriented grains in quartz schists. On the other hand, randomly oriented grains of framework crystals, of felspar and quartz, must often present spaces of at least the order of size of the unit cells to either side.

Growth of Quartz Porphyroblasts

We may thus visualize the existence between two quartzes of a film accommodating water as H and OH ions and perhaps as molecules. It is probable that at low temperatures the free charges to either side of the channel between A and B (fig. 21 *c*) create the same effect as if the solution were super-saturated, but with increasing temperature this condition must change and the water in the film become undersaturated with regard to the small crystal. Then unit cells would be disrupted in turn and $(SiO_4)^{4-}$ ions would be released into the solution. In general, the release would be from the small crystal and any freed $(SiO_4)^{4-}$ ion would simply move across from one crystal to the other, reorient itself and grow on the larger lattice. Succeeding ions would do the same in sequence and eventually the small crystal would be "absorbed" by the larger. In a rock consisting of small quartz crystals any larger one of these could thus build

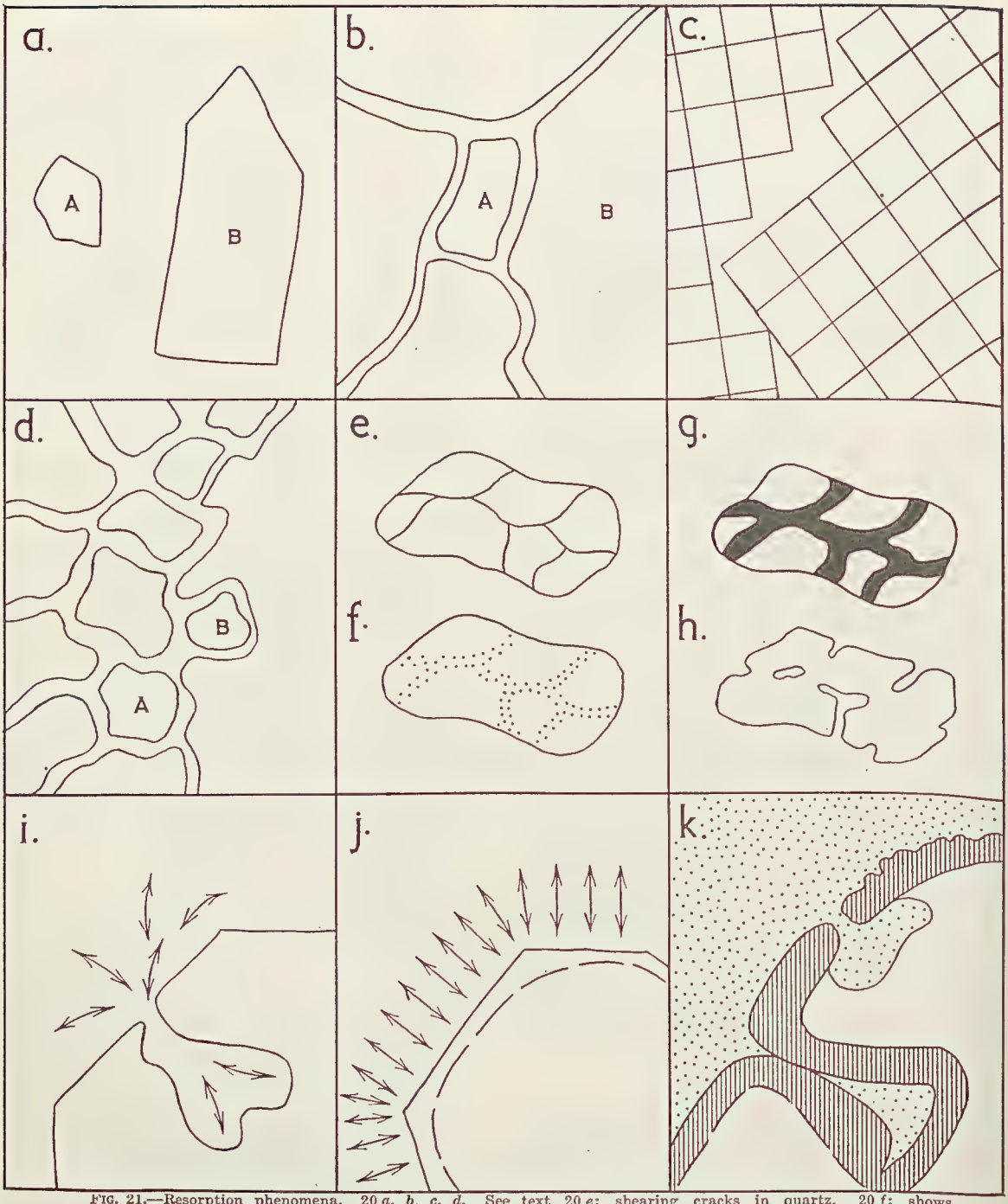

FIG. 21.—Resorption phenomena. 20 *a, b, c, d.* See text 20 *e*: shearing cracks in quartz. 20 *f*: shows a possible distribution of shearing strains in unbroken quartz crystal. 20 *g*: shows complete resorption of shear zones (*Cf.* plate D, fig. 4.) 20 *h*: shows partial resorbtion in a lightly strained crystal. 21 *i*: shows a picture of directions of diffusion of ions which is only true when a crystal has different solubility in different parts. 21 *h*: shows the pattern of diffusion of ions with a homogeneous crystal. 21 *k*: shows the effect of regrowth (shading) in closing resorbtion cavities. (*Cf.* plate C, fig. 6.)

itself into a porphyroblast. The operation of this process in quartz porphyries is well demonstrated by the pimply growths that can be seen on the margins of quartz crystals in thin sections. To make this obvious and unequivocal (in that there can be no possibility of magmatic origin) a porphyroblast that has grown in a quartzite has been chosen for illustration (plate C, fig. 5). Here the rock is an unstressed quartzite from Mount Bischoff, Tasmania; it forms the upward continuation of a quartz porphyry dyke. In more normal quartz porphyries quartz often grows in the same manner by the aggregation of very small quartz crystals such as occur in quartz felspar hornfels (Goodspeed, 1937).

Accompanying sericitization is a widespread saturation of surrounding rocks by colloidal silica; this sometimes silicifies the rocks with chalcedonic silica (Scott, 1954, p. 137), or at higher temperatures produces a hornfels with minute quartz granules. There seems to be a wide variation in the size of granules which might be formed in this way, so that when they are built up into larger crystals there is a corresponding variation of the "pimpliness" of the resultant porphyroblasts—for example, in thin section a fine-grained hornfels shows a relatively smooth outline and a quartzite shows a rough outline and so on.

Where obstacles, such as the minute felspar grains of hornfels and adinoles, lie in the path of growing quartzes they are not pushed to one side as happens in the growth of garnets. Nor does the quartz simply engulf the impurity and then in some unspecified way "clear itself", but the offending particle is chemically resolved and goes into solution. In fig. 21 *d* any particle of felspar such as A which is in equilibrium with the solution and its neighbours, will pass out of equilibrium if it is put into a position B where it is threatened with "capture".

In crystals a smooth outline represents a smaller relative surface and a lower free energy than does an irregular outline so that in adjustment towards lower temperature equilibria there is usually a tendency for crystals to fill in their depressions and round out their outlines. Despite the absorption of small crystals outside an optimum outline there is, it seems, a greater attraction on surfaces in the recesses of the crystal than on the protuberances for any spare ions which might be in solution. In the example fig. 21 *d* there must therefore be some tendency for solutions which lie in the recess around a potential inclusion of felspar to be poor in silica ions. If conditions are such that a felspar at A is in equilibrium with the quartz, the sericite and the solution, then the tendency at B must be for the mineral to be out of equilibrium. It will react with the solution to form sericite and silica in solution, and this silica will be deposited on the inside of the cavity. If a non-reactive compound lay in the path of the growing quartz it would be included in the grain, but since potential inclusions are usually silicates and are higher than quartz in Bowen's reaction series most potential inclusions are resorbed. Quartz will, however, capture kaolin and water which may be considered lower in the reaction series, and chlorite which is near quartz.

Resorption of Quartz

The formation of resorption cavities in quartz crystals illustrates the principle of grain growth very clearly and demonstrates the extreme sensitivity of equilibria in intergranular films. When stress is applied to crystals, potential energy is imparted and the result is a warping or disordering of the ionic lattice. This energy, which is in excess of that normally possessed by the crystal allows a strained crystal to dissolve with greater ease than it would were it unstrained (Barth, 1951, p. 305).

Returning to the broken crystals of plate D, fig. 4 and to fig. 21 *e-h* we see again that quartz crystals may be unevenly strained throughout their lattices. A result of this is that strained crystals can never be in perfect equilibrium with enveloping solutions, and if the latter are saturated with respect to the unstrained parts of crystals they must be unsaturated with respect to the strained parts. If equilibria are critical and no other factor intervenes there must be some tendency towards solution of strained parts of crystals and the formation of resorption cavities. Ions released in this process must tend to migrate through the intergranular film and be precipitated on the unstrained parts of the same or adjacent crystals. (Fig. 21 *k*.)

Shapes of cavities are difficult to explain without this straining hypothesis. In any alternative thesis one must assume that solutions (magmatic or watery) must have had different solvent powers at different points around a crystal. This implies that ions migrate in the curious pattern of fig. 21 *i* and that they do not obey the known principles of diffusion. Most authorities would agree that the pattern of diffusion around crystals is that shown in fig. 21 *j* and that diffusion gradients around crystals are highest at corners and not in the middle of faces or in cavities. In general, crystals tend to be rounded off at corners.

Specimen quartz crystals dissolved in the laboratory do in fact become rounded, and so do felspars when resorbed in lavas.

Now, if it is accepted that resorption cavities indicate differential solution and that solutions themselves may not vary in solvent power the only alternative seems to be that the crystal being resorbed has variable solubility. Further, if the crystal has a uniform elemental composition any variation in solubility must be attributed to the arrangement of its particles, i.e., to a warping, straining or other disordering of its lattice.

This principle does not necessarily apply to minerals other than quartz, for in many crystals strain is taken up by gliding on cleavages, or by twinning; and many minerals (e.g., perthites) have variable compositions and solubilities in one crystal and this masks strain resorption effects.

The strain resorption effect can explain a number of puzzles in the literature and in the field. Misch (1949, p. 388) and much earlier Wadsworth

(*loc. cit.*) have proposed that resorption cavities are a result of crystal growth. Where growth occurs at the same time as resorption, the neck of a cavity tends to become constricted and finally to close up altogether (fig. 21 *k*). Only in this respect does Misch's explanation seem to be valid.

Up to this point a two-dimensional view has been taken of cavitation but it is a small step to imagine resorption as occurring in a plane normal to rock slices, and so to account for isolated islands of groundmass in the centre of crystals (plate C, fig. 6). It is easy now to see why it is that resorbed crystals should be so much more common in the dynamically stressed quartz sericite schists at Lyell than in the quartz porphyries. In general, it seems that schisting and porphyritising are complementary and that conditions favouring the one tend to eliminate the other. In eliminating shearing stress metasomatism has the same function as fluidity has in magmas, and it appears that the rocks of metasomatic environments will transmit shearing stress only for very short distances. Where stress is particularly intense, crystals are broken down into small units, but resorption immediately removes strain and regrowth of crystals follows. So rapid is this reaction that in the West Coast Range it is only around the latest faults that schisting occurs, and even along the Lyell Shear the porphyroids are characteristically non schistose.

Felspar Porphyroblasts

The growth of felspar porphyroblasts is similar to the amoeboid growth of quartz crystals. Orthoclase and oligoclase porphyroblasts are respectively shown by plate B, figs. 3 and 5, and so far as growth is concerned the only difference between these and quartz crystals lies in the lack of resorption cavities and in the presence of zones and zoned inclusions.

Zoned Felspars

Zoned felspars in granites present one of the greatest difficulties to theses of origin of granites by dry diffusion. It seems improbable that a process of diffusion which allows the formation and preservation of unhomogeneous felspar crystals can at the same time permit the homogenising of wide granitic terrains made up of such crystals. In soda rich felspars it is common for zones to be only 0·1 mm. wide, and for successions of zones to vary in rhythmic or cyclic fashions (Barth, 1951, p. 150). These indicate sudden changes and reversals in composition of felspar and of the solutions or magmas which might have deposited them, and thus set problems for magmatists as well as dry diffusionists.

Interpreting crystal growth in terms of intergranular films provides a very feasible mechanism of origin of zones. One might visualise the growth of a felspar crystal on the wall of a pegmatite vein and imagine that composition, pressure and temperature of the solutions surrounding the crystal might vary because of opening or closing of the fissure. Then the growing crystal would be coated with layers of varied composition. As each layer was precipitated it would be out of circulation, and if there was no dry diffusion it would remain as a zone. Now, if the pegmatite vein is as in an earlier example, reduced to the size of an intergranular film, the zoning of crystals in solid rocks might be explained.

One might visualize a felspar as bathed in and growing in an intergranular film and that as the crystal grew the neighbouring crystals were resorbed to make room for the new felspar (fig. 22 *a-c*). The concentration of ions causing this growth and resorption might vary depending on steady migration of thermal zones or on sudden fluctuations of pressure in the continuous fluid system of pores.

It is because of such fluctuations that zoned inclusions in felspars become possible. As long as growth is slow and changes of composition of enveloping solutions are gradual there is time for the migration of ions, the filling of cavities and the resorption of potential inclusions. With sudden pressure changes it is possible for equilibria to change swiftly and for there to be sudden precipitation of a new kind of felspar whose constituent ions are evenly distributed through the solutions. With even distribution of ions it is possible and almost a consequence for growth of felspar crystals to be concentrated on the projecting pimples which thus grow together and capture inclusions.

Turning to the broader picture of intergranular films in rocks, it is possible to account for the metasomatic replacement of whole rock sequences. For simplicity it will be assumed for the moment that we have a quartz sandstone in which all pores and smaller intergranular spaces are pervaded by water at high temperatures. Clearly a recrystallization of the whole can be effected by exchange across intergranular films without a single ion moving more than its own width. This would satisfy the economy of movement of silica or oxygen as desired by Poldevaart, Read and Barth (*loc. cit.*). Now, if we have a uniform greywacke of the composition of granite, and if it be under conditions where it might crystallize as that rock, the maximum distance of migration of any element would be of the order of size of the constituent mineral grains. Since most of the rock is silicate there would be no need to require any of the larger ions to migrate more than their own width. These would stay roughly in constant positions while smaller ions migrated quite small distances through films, and readjusted themselves to the new equilibria. If the rocks were bedded and of variable composition, it is clear that there might be need for migration of ions from one bed to its neighbour, over distances of many feet. If large silica ions had to be moved there might be some difficulty, but were the formation permeable as in a conglomerate, or if the time factor were large, there would be no problem. On the other hand, if a bed like dynamically compacted Miners' Slate were involved, there would be no intergranular films between crystals and there would be no ready alteration of this rock.

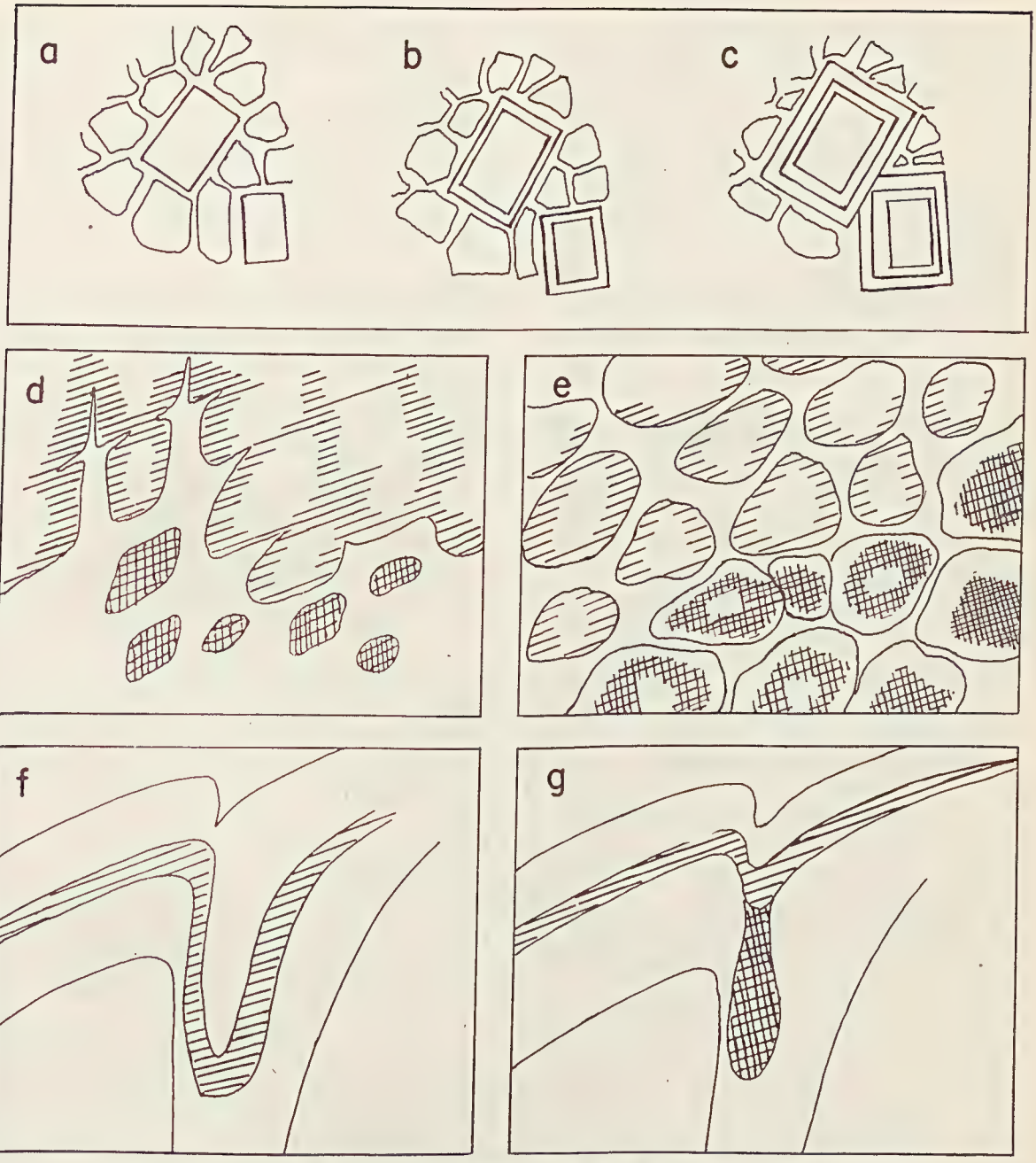

FIG. 22 *a*, *b*, *c*.—Stages in the growth of zoned felspars. 22 *d* and *e*: show how haematitic rocks and pebbles (shaded) may be captured into a zone of magnetite (cross hatched). 22 *f* and *g* show how a large part of a mineralized front may be captured.

The rules governing films and generally applying to film metasomatism of porphyroids can be set out thus:—

1. The thickness of films can be defined as the minimum thickness which, at the temperature prevailing, would allow he migration of the largest ions involved in silicate reactions. Films probably need be no larger than one order greater than the diameter of the largest ions. For practical purposes a rock being altered by means of such films can be regarded as solid throughout its metamorphism, and as only slightly less solid than granite at the surface today.

2. A slight solubility of silicates in water is all that is needed for exchange, because the distances of migration are so small. Obviously there must be some equilibrium between temperature, rates of migration, width of channel, such that the minimum width of channel would be maintained for each set of pressure-temperature conditions, i.e., at high pressures, low temperatures, and with low solubility the rates of diffusion and width of channels would be small. With increasing temperatures channels would widen until at melting they involved the whole rock.

3. Although water content of the rock might be low, say 2 per cent, all reactions might proceed in great dilutions of water, say 99 per cent.

4. The water and volatiles of the pore spaces need not in this static process ever be used up. Their effective role is comparable with that of catalysts.

5. Intergranular exchange will probably be at a maximum at the lowest depth compatible with high temperatures and retention of water.

6. The process will be at a minimum at great depths and in rocks with common orientations of crystal lattices (i.e., dynamic and deep seated metamorphism must generally be opposed to porphyroid).

7. For the common large ions of silicates the distance of migration is very close to the minimum which can be arranged with any other device, and need be little more than the diameter of the ion.

8. The equilibria existing across fluid interspaces are extremely sensitive to changes of temperature, pressure and concentration.

9. The process can happen only once to a given series of sediments. These rocks may, however, be subjected later to dry metamorphism.

10. The problem of the source of energy required to melt rocks in magmatic theory does not enter here, for very little rock is in solution at any one time, and because solutions are dilute and watery temperatures are at a minimum.

11. The mechanism does not depart from the already accepted principles of magmatism or metamorphism, and provides an important bridge between them.

Amplifying the last point, conventional magmatic schools accept and even proclaim the following ideas which are necessary or relevant to the hypothesis of intergranular diffusion and metasomatism. It is widely agreed that all the minerals of the alkali granites may form at relatively low temperatures from dilute water solutions (i.e., in pegmatites). It is agreed that diffusion in such solutions must be much swifter and more effective than is diffusion in acid melts and is much aided by volatiles. It is agreed that the parent material of granites may, and probably does, contain large amounts of water (Goranson, 1938).

Shand (1950), among others believes that a magma may to an appreciable extent consist of crystals; if this is so, and if the magma contains large amounts of water, the interstitial fluid must be very rich in water and must occupy narrow channels which in principle must be not unlike the intergranular films advocated here. There must be some point in any theoretical crystallization of granite magma where all magmatists are compelled to agree with Shand. Further, if and when crystallization from magmas has proceeded almost to the "last drop" and residual fluids finally react with early minerals to produce granite, the magmatist must logically find some stage where he is in complete agreement with this account. He cannot, therefore, object to the film mechanism on any point of principle.

Finally, the reaction series as proposed by Bowen (1928) and accepted by two generations of petrologists applies fully to the account given here for the origin of quartz porphyries. That series indicates that a succession of minerals may be precipitated in turn from a solution, and that at each stage the solution becomes enriched in the constituents of lower members. In the final instance orthoclase, then muscovite, and then quartz are precipitated from the "magma". Alternatively, the series may be interpreted to mean that any one mineral may react with a "more acid" melt to form the next lower member in the series. Since it is improbable that quartz or muscovite can separate from dry quartz muscovite melt, those minerals must then be formed either by reaction of felspar with residual melt (clearly the only residual melt which can possibly exist with felspar at this stage is water) or must be precipitated from water solution (e.g., as in pegmatites). The first alternative is clearly the case of the quartz porphyries and the second directly implies that the interstitial quartz and muscovite of the potash granites has crystallized out of pegmatitic intergranular films. Although perhaps never expressed in these terms this is the magmatist's, not the granitiser's, view of formation of quartz and muscovite.

The Dora Conglomerate.

The Dora formation was described (Part I) as consisting largely of quartz porphyry conglomerate interbedded with occasional slaty beds, and as passing up near the top of pyritic chlorite beds and haematized conglomerate. At that horizon there is some passage through haematitic rocks from the porphyries below into the quartz conglomerate above.

It seems probable that the Dora formation was originally a felspathic greywacke conglomerate, perhaps quartzose towards the top, and that during the earlier stages of metamorphism it was permeated by felspathising solutions. Here were formed albite-oligoclase rocks of keratophyric types just reaching to a grade with biotite. The correlative formation at Lynch Creek has been described as bearing tremolite, but metamorphism there was gradational and rather mixed. At Lake Dora the entire formation is relatively uniform for metamorphic grade and occupies a marginal position between the biotite-chlorite sub-facies and the albite epidote-amphibolite facies of Turner and Verhoogen. The same formation on the other side of the range and below Mount Geikie contains the

hornblende-bearing rock described by Scott (1954, p. 140). The latter rock appears to belong to a slightly higher grade, viz., the albite-epidote-amphibolite facies.

The conglomerates in the immediate vicinity of the Red Hills copper prospects were not intensely pneumatolysed at a late stage and thus remain for our inspection, but elsewhere the Dora formation was widely injected by heated waters and converted to quartz felspar porphyry and quartz porphyry. The formation was pervaded by hot water, but it is evident that there was no great flow of water for there is little intense sericitising.

Because the system moved towards an equilibrium involving quartz and sericite it follows that quartz pebbles and slabs of slate in the formation would be unaffected by the quartz porphyritising. Had previous felspathising been intense everywhere there would have been no quartz pebbles, nor perhaps even slate fragments, left in the formation, but in some localities (the King Bridge) quartz pebbles were by chance unaltered by felspathising and, of necessity, unaltered by later quartz porphyritising. Late injection, which porphyritised the whole Dora formation and the Jukes Breccia, ignored quartz pebbles in those strata and in the Owen Conglomerate. Slaty fragments were not left entirely unaffected by this process, for their chlorite was destroyed, they were substantially leached of iron, and they were converted to yellowish sericite. Now they tend to be friable and have a weathered appearance.

At Lake Dora the matrix of the conglomerate often bears porphyroblasts of quartz and felspar and is like most of the pebbles, but it is almost always green and chloritic whereas the pebbles are often a dull brownish red.

Along sheared zones like the North Lyell Fault at the King Bridge, the matrix of pebbles consists almost wholly of sericite without porphyroblasts of quartz or felspar. This difference in matrices is to be expected between the rocks of stressed and non-stressed environments. In a conglomerate any shearing stresses must tend to be concentrated in the weak matrix of the rock, and pebbles must tend to be rotated. Any concentrated shearing tends, as we have seen, to favour the growth of sericite and to suppress the growth of quartz phenocrysts. The occurrence of sericite as the matrix of the drawn out porphyry conglomerate at the King Bridge, is thus quite consistent with the history given for rocks at Lake Dora.

Sporadically, as for example along Roaring Meg Creek, a third textural variation in the porphyries occurs. Here the porphyry consists of a slate breccia and it is only the matrix which has been porphyritised. It seems that parts of the greywacke sequence consisting of thin alternating bands of slate and tuffaceous sandstone reacted to shearing by breaking into a breccia of compacted slate and sandstone. As already shown, slates are not readily altered; in the first instance they are not readily permeable and in the second they are made of sericite and chlorite and would have little reason to react with solutions forming the sericite of the quartz porphyries. The result of metamorphism of such a mixture is a breccia with a cement of porphyry or a porphyry filled with slate fragments. For similar reasons it is possible to have quartz pebbles or slaty pebbles with a quartz porphyry matrix. In the Magnet area of Tasmania a silicified limestone (probably the Smithton Dolomite) does form such a breccia.

Apart from Tasmania, a common mode of occurrence of quartz porphyries is as thick conglomerates or inclusion crammed breccias. Examples of the latter are exposed on the Buller River, New Zealand. (Morgan and Bartrum, 1915), and are interpreted by the writer as metamorphosed slate breccias in which the slaty fragments have been unaltered while the permeable matrix has been porphyritised. On the same river the younger Hawks Cray Breccia (Wellman, 1950) has to the present writer been similarly but less intensely porphyritised and mineralised with pyrite and uraniferous minerals.

Further afield the vast (15,000 ft. thick) Calumet and Hecla quartz porphyry conglomerates of the Michigan copper mining district are like the Dora Conglomerate in that they end abruptly against a mineralised fault. Almost every writer on these conglomerates has described them as having been permeated by metasomatising solutions, and has commented that they consist of felsite and quartz porphyry pebbles derived from some unknown source of batholith dimensions (Butler and Burbank, 1929, p. 53).

It is relevant to note here the common occurrence of breccia pipes and breccia dykes of quartz porphyry in copper bearing rocks. These have been observed in Arizona by Anderson *et al* (1955, p. 42) and described as explosion pipes, and the ? "relict pebbles" in some of them have been attributed to abrasion during transport by gas explosions in volcanic necks. This writer believes that they represent replacements, along pipes and fissures, of pre-existing breccias and conglomerates of lava and sediments.

The world literature on the porphyries, and particularly of those associated with copper and iron in Fennoscandia and Canada, is so full of references to thick quartz porphyry conglomerates, and has so few references to solid quartz porphyry bodies, that the writer believes that a very common and possibly *the most common mode of occurrence of the large quartz porphyry masses quoted in the literature is not as intrusions but as beds of conglomerate or breccia.*

Replacements at Sharp Contacts.

The simplest and, at this stage, most instructive example of replacement at a sharp contact is at Lyell where quartzitic Owen Conglomerate is replaced by haematite (plate A, figs. 2). The field phenomena have been described (Part I), and microscopic study simply confirms the findings based on hand specimens. The elementary fact is that there are no intermediate stages of change between quartz and haematite. The first figure shows the phenomenon described earlier from hand specimens, viz., that chert, quartzite and vein quartz are replaced in that order. In hand specimen the

first haematite to appear replaces the cherty matrix between pebbles, and under the microscope the first haematite replaces the matrix between the quartz grains in the quartzite. There is some suggestion in thin sections that small grains are replaced before large, and strained before unstrained grains, but this adds no new principle. Plate D, fig. 3 provides the most significant information, namely, that iron has migrated along grain boundaries. In a complementary manner it shows also that silicon or silica ions must have emigrated from the rocks. Presumably such emigration was also along grain boundaries, and at first sight it appears that as iron moved forward silica must have moved back along the same path. There is a limit to this, however, for the silicon has clearly not gone backward: there is only purer and purer haematite in that direction. The silica must in some way have passed through the completely silicified conglomerate. There is no doubt that the conglomerate was locally silicified at this stage, for the pebbles are often broken and replaced by haematite along cracks which run across matrix and neighbouring pebbles. $(SiO_4)^{4}$— ions must, then, have passed through the quartzite fissures and along boundary films or, conceivably, by a process of exchange through crystal lattices. On the other hand, many of the quartz grains in the illustration (plate D, fig. 3) are now isolated by a surrounding layer of haematite. If grains like these were replaced by haematite to form solid haematite pebbles there must have been some migration of $(SiO_4)^{4}$— ions through the surrounding wall of haematite. As the haematite is specular and is made of small grains, it seems that silica must have moved through the intergranular films surrounding the individual haematite grains. Furthermore, it is clear that if there was a continuing replacement of quartzite by haematite there must have been continuing reinforcement of iron ions moving up through the haematite.

It is concluded that iron and silicon or their oxide ions can each move through the films between quartz grains and between haematite grains. And now we can ask: do they move in watery films, in disordered marginal phases of crystals, or in a combination of both? Since chert grains are wholly replaced crystals of quartz are untouched, it seems that the films might have had the same constitution and composition as the chert (i.e., be disordered and contain water).

It seems most probable that the ferric ions may migrate through pores and films for some distance in front of the points where haematite crystals are first observed and that along with silica and hydroxyl ions in those places they form a disordered phase. It is presumably this thin dispersion of ferric ions which gives the rose colour to much of the conglomerate, and it is the first formation of crystalline haematite which causes the sudden change of pebbles from pink to black.

Replacement of Quartz by Sericite.

Although the haematite zone lies at the base of the zone of silicification it is not always equally thick or intense but may vary from fifty to zero feet; if thin it may contain many unaltered pebbles of quartz. The chloritising and sericitising of the haematitic quartzites provides the sharpest and most dramatic contact of all.

The replacement of quartzite by sericite at this contact is real enough, although the phenomenon has not often been recorded and few workers would find it feasible. Replacement by sericite along grain boundaries is similar to that just described and presents the same problems of migration. Replacement is not simply by mica but involves some chlorite also, and it can be concluded that there has been a migration of aluminium in one form or other along intergranular films. In this process the quartzite is progressively replaced along grain boundaries so that quartz grains become smaller and finally disappear (plate A, figs. 3, 4 and 5). This disappearance takes place at different rates at various points along the outcrop, so that in some areas there are quartz sericite schists extending beyond the contact for 20 yards, and in others only for an inch.

Differential schisting of the sericitic rocks as compared with the quartzites is to be expected because of the very soft nature of the sericite, and this schisting, together with the unschisted quartzites and haematite "pebbles", gives a very convincing but false appearance of unconformity.

Very similar replacements of quartzite by sericite have been described for the sub-Huronian unconformity below the Ajibik Quartzite in Michigan; Lamey (1934, p. 263) states, "Another unusual phase of contact metamorphism is the sericitisation of an impure quartzite", and it was in such a context that Van Hise (*loc. cit.*) described the process of "mashing" of quartzite.

Adjacent to the quartz-schist contact at Lyell, is the sharply defined contact of chlorite against haematite. This contact can be readily traced for miles, for on one side there are exclusively green chloritic rocks (except for the two islands at Lyell), and on the other there are exclusively red and purple haematitic quartzite. Replacement here follows the previous patterns and calls for little comment. Confirmation of this type of sharp contact is provided by another example from Michigan described by Butler and Burbank (1929, p. 53): "In the iron rich boulders in the Calumet and Hecla Conglomerate the rock was chloritised at the front of the replacement wave and replaced by copper a little nearer the source, both processes evidently having been in progress at the same time and, in places, but a fraction of an inch apart" . . . "The front of the replacement wave in the amygdaloid is marked by the destruction of haematite". It is remarkable to find that copper deposits from many parts of the world present the same kind of zoning and this confirms the writer in his interpretation of the zoning at Lyell.

Replacement of Quartzite by Felspar.

At Darwin Spur (Snake Spur, fig. 16 c) and across the main peak of Darwin summit, the Tubicolar Sandstone is felspathised and barely distinguishable. On the Spur, however, the formation is readily recognizable and there it is horn-

felsed and bears small pseudomorphs of kaolin and sericite after felspar (plate B, fig. 4). Exposures here indicate rather more clearly than at Lyell that the felspathising front at one time has been higher than the zones of pyritising and sericitising, At present the pyrite zone is 300 feet below the spur of Darwin, and the felspar zone should be below that again. At Lyell a very large part of the present sericite chlorite zone was completely felspathised at one stage, and it must be concluded that in both places there has been some fluctuation of zones. The pressure sensitive system of veins, fissures and films which apparently extended along the length of the range must have fluctuated violently when earth movement occurred, and zones may have retreated from a high optimum to the lower level seen at present.

Nature of "Pseudo-unconformities".

The sharpness of the contacts just discussed is not constant everywhere between the same pairs of rocks, for irregularity has been caused by the following factors:—

1. Chemical heterogeneity of the replaced rocks.
2. Textural heterogeneity of the replaced rocks.
3. Kind of material introduced.
4. Gross texture of the formations adjacent to the contact.
5. Level of isograds relative to the contact.
6. Concentration of reacting solutions.

The effects of these factors may be illustrated by descriptions of the following contacts.

Haematite Pebbles at Lyell.

Preferential replacement of chemically uniform quartzite pebbles has already been explained as largely due to textural differences. The same conclusion has already been arrived at by Goodspeed and Coombs (1937) who have shown how a sheared rock has been more readily replaced by diorite than unsheared rocks of the same composition. A significant point at Lyell is that individual pebbles of quartzite which have been completely replaced by haematite are sometimes quite isolated among wholly unaltered pebbles. This must be accepted as fact, and it seems that Goodspeed's conclusions may be applicable to many kinds of replacement. It is pertinent to the next section that, despite earlier views, there are probably no workers who would today regard the haematite pebbles at Lyell as derived laterite, and the contact as a true unconformity.

"Derived" Quartz Porphyry Pebbles.

At Lake Dora the basal beds of the Owen Conglomerate contain large quartz porphyry pebbles similar to the underlying quartz porphyries. These underlying porphyries have been described as keratophyres, and the overlying pebbles have been regarded by Carey and Banks (1954, p. 250) as evidence of unconformity. The writer has no objection in principle to unconformity at this stratigraphic level, and his arguments can readily be interpreted to mean that metamorphic contacts are likely to locate themselves at unconformities. Despite this, or even because of this, it is contended that the evidence of "derived" pebbles as indicating unconformity is here negative, for the pebbles can be explained adequately within a porphyritising hypothesis.

Quartz porphyritising of the Dora Conglomerate was accomplished under conditions involving precipitation of quartz, so that when quartz porphyritising solutions came in contact with the base of the Owen Conglomerate the quartz pebbles of that formation were not affected; but the same conditions in the same strata must have caused alteration of any felspathic pebbles to quartz porphyry just as readily as they did in the Dora formation. While the abundance of quartz pebbles close to the contact did not apparently affect the concentration of silica in solution, nor disturb equilibria, it seems probable that at higher levels in the formation concentrations of silica were strong and temperatures were probably lower. Under these conditions felspathic rocks were wholly replaced by chalcedonic or opaline silica.

In the same way as in the porphyry replacements there is some preferential replacement of certain rocks by haematite. It has been shown that haematite replacements of quartzite may be very delicately controlled by the energy state of quartz particles, and it appears that replacement of other rock types according to composition may be just as delicate. Although the haematite zone is well defined, and the position of the zone as a whole is independent of the composition of the original rocks, the top of the zone is irregular and the order of replacement of pebbles is often related to the original composition of the replaced pebbles. At Red Hills, for example, wherever a slab of haematitic slate or specular schist occurs among quartz pebbles in the sensitized border of the zone, the writer deduces that there has been a replacement of original slate or chloritic schist and that individual flakes of chlorite have been replaced by individual scales of specular haematite (see Part I, p. 231).

The contact at South Darwin is similar to that at Red Hills, for the Darwin granite had an origin little different from that of the felspar porphyries. The main differences lie in the extreme narrowness of zones at Darwin, and in the presence of magnetite at the contact. It appears that haematite pebbles were reduced to magnetite at relatively high temperatures, and that this process affected pure and impure haematite rocks. The result is that below the contact, pebbles of black magnetite or of greenish black chlorite-magnetite occur instead of the purple or russet haematitic pebbles that are typical above the contact. This relationship is common to contacts of many magnetite haematite deposits all over the world, and there is nothing remarkable about it. The phenomenon is, however, important to this thesis, for it must be explained why, in an environment of advancing fronts, this particular occurrence of haematite should have been left behind to be enveloped by high temperature zones, and to be altered to magnetite.

The answer to this problem is best given in terms of structure (fig. 22 *d*.). The diagram shows masses which may be of any size from two inches to a hundred yards or so across. During metamorphism, as temperatures rise and fronts advance, such blocks may be isolated from their neighbours and the advancing fronts pertaining to each block may also be isolated. With continuing metamorphism the frontal minerals of each enclosure become restricted to smaller and smaller spheres and finally form concentric or nodular inclusions. This applies to those cases where the original enclosure was either an angular fragment or a rounded pebble. Where the original particles were of haematite and were pebbles, as at South Darwin, there is only a slight diminution in size and the individual pebbles are substantially the same as they were before metamorphism. This is essentially Reynold's (1946) explanation of the zoning of basic xenoliths in granites; and the same explanation can be applied to the occurrence in certain nodular porphyries of zoned magnetite spheroids, e.g., in the Kiruna area (Geiger, 1910, pp. 704-6).

On the larger scale (figs. 22 *f* and 22 *g*), favourable structures, such as the sharp syncline at South Darwin or the overfold of Mount Sorrell, produce isolated or nearly isolated masses in which haematite and sulphides may be trapped, and in which zones might be compacted within a small compass. Under these circumstances rocks of the haematite zone may be converted into masses of magnetite such as occur at Mount Darwin, and thus in a general sense one might also account for a number of ore enclosures in granites. For example, the tourmaline nodules of the Heemskirk granite probably represent the result of continued restriction of a volatile front around shale inclusions in the granite, and the tin pipe at Heemskirk may represent a large scale structural trap. The localised abundance of volatiles in these trap structures is indicated by vughs (gas filled cavities) which are sometimes lined with cassiterite, muscovite, and tourmaline crystals (*c.f.* the drusy nodules of Geiger).

So far in this account, the reasons given for the location of sharp contacts at stratigraphic boundaries have been related to the temperatures and permeabilities of the rocks concerned, rather than to their original composition. This has served to emphasize that on porphyroid metasomatism the role of diffusion is more important than thin or local variations in composition in the unmetamorphosed strata. Thick sequences of monomineralic rock such as quartzite may, however, be important in controlling the trend of metamorphism.

In a general sense the trend of metamorphic processes is to produce a large scale re-distribution of elements and minerals in the crust, such that an increased chemical and mechanical stability is reached, and such that in the ideal instance an equilibrium is established between pressure and thermal gradients and rock types. For this reason, metamorphism only becomes possible when there is some pre-existing lack of equilibrium in the rocks. Conversely, if rocks in the crust should have already been arranged by some curious accident into zones similar to metamorphic zones there could be no metamorphism. Such a situation is unlikely to arise for the principal causes of disequilibrium are the processes of weathering, sedimentation, and sedimentary burial; nevertheless, sedimentary processes do produce some rocks which coincide in composition with those resulting from metamorphism, e.g., quartzites of the Owen Conglomerate. If, during metamorphism it further happens that such a bed of quartzite coincides in position with a metamorphic zone of silica precipitation, that bed must tend to prevent the migration and to stabilise the position of that zone. This is not an improbable situation for if there is an advance of zones such as has been described for the West Coast Range, the zone of silicification must tend to be halted at any thick quartzite bed such as the Owen Conglomerate. This does not mean that quartzite may not be altered (alteration has occurred at Lyell), nor does it mean that the zone of silicification should always reach up to the conglomerate (it does not do so in areas of gradational metamorphism); and it does not mean that thick quartzites like the Owen Conglomerate may not be completely replaced.

It does mean that the thick Owen Conglomerate presented a barrier to the advance of fronts, and that this was independent of the physical factors discussed earlier. The quartzite did not only tend to halt the zone of silicification but it also seems to have caused the telescoping of the succeeding zones. This telescoping and concentration might account in some part for the density of the pyrite zone below the quartzite contacts, and the diffuseness of pyrite in areas of gradational zoning may simply reflect the normal system of zoning. The common abbreviation of zones below quartzites at many granite contacts throughout the world may be explained in the same way. The abrupt arrestment of granitising processes at contacts with quartz haematite or quartz magnetite rocks is, perhaps, most forcibly described by Lamotte (1943, p. 116), who relates how fine-grained magnetitic quartzites have presented a barrier to transport and migmatising, and how in no single case has felspathising been affected across this barrier. Lamotte, as well as the writer, distinguishes the porphyroid type of metamorphism from others, and draws attention to the difference between the contacts of granites with siliceous and alumino-siliceous rocks.

NATURE OF SOLUTIONS.

The important role of sodic solutions in metasomatism has been stressed by many workers in independent studies of spilitising, granitising and sulphidising. Some, like Gilluly (1935), relate the two former processes to a common cause, the rising of sodic solutions along deep seated faults. Others, like Graton (1940, p. 251) have emphasized the importance of alkaline solutions in the transport of sulphides. So far as the state of water solutions is concerned the writer would agree with Graton that injection of rocks by steam is unlikely, and that injection below critical temperatures must be by superheated water. The behaviour of water at higher temperatures is, however, very difficult to gauge. Apart from surface tension effects mentioned earlier, it has been shown by Gillingham

(1948) that water above 400°C, and with free sodium ions, may dissolve appreciable amounts of silica.

Given temperatures of this order and sodium-bearing solutions, there seems to be no difficulty affecting the theses of intergranular films and of sodium metasomatism. The source of sodium as carbonate and silica as proposed by Eskola (*loc. cit.*) for the spilite reaction is, however, purely assumptive and this applies to most hypotheses concerning the origin of soda rich solutions.

There are two possible sources of those solutions, one by differentiation of sub-crustal basaltic magmas, the other by a regenerative or circulatory system whereby sodium is buried in the earth and then released. There is little doubt about the feasibility of the former process, for the oceanic volcanoes do give rise to sodic rock types and release huge amounts of carbon dioxide. The solutions released are, however, rarely saturated with silica and when involved in metasomatism appear to give rise to under-saturated rocks. This is well understood, and it is possible that such solutions could be formed at depth and rise along fault planes. It happens that metasomatism of granitising or spilitising type is rarely associated with undersaturated rocks (the nephelinitising at Haliburton is a notable exception) and some source of silica as well as soda is required to allow of granitising.

In a regenerative system these requirements can be met, and Eskola's reaction which has been shown to be reversible (Eskola, see Barth, 1951, p. 286) provides a possible explanation of such a system. According to Eskola the calcic plagioclases tend to be stable while the sodic varieties tend to be unstable at high pressures. Although experiment has so far demonstrated this reaction only for felspars between albite and andesine, the principle can be reasonably extrapolated throughout the full range of plagioclases. It becomes feasible in this view that normal sediments containing sodic plagioclase or elements in the proportion of that mineral may, on deep burial, react with lime rich minerals to give rise to anorthite molecules and ionic solutions of soda and silica. This scheme fits in with the regenerative system already proposed for the origin of the water involved in metamorphism and in the tranport of heat from depth.

It may be imagined that in the rocks at depth in the slowly subsiding Zeehan Syncline there was a vertical column of rocks in which the plagioclases at different levels were all being altered by pressure to more calcic types. At all levels, too, silica and soda were being released and collected in the efferent system of veins for upward migration. Such migration probably occurred with each phase of movement of the major geanticline, and it would be difficult to separate any one stage (such as the spilitising of the basalts) from any later phase of metasomatism. With this mechanism there is not, as with other devices, any problem of adequacy of the source in producing the requisite bulk of soda or silica for metasomatism, for subsidence and deep seated metamorphism might easily keep pace with granitising.

It follows from this argument that at some depth in the Zeehan Syncline calcic felspars, or masses of gabbro or of anorthosite must have been formed but there is no evidence that these occur. In other parts of the world where the crust has been deeply buried there is ample evidence of metasomatic formation of anorthosites, e.g., in Fennoscandia and Canada but for the purpose of this account it will simply be assumed that such anorthitising is possible and that it may occur in any deeply depressed region.

An important consequence of the aggregation, transport and dispersion of sodic solutions, is that this mechanism makes possible the collection and transport of sulphides and allows their ultimate deposition in disseminations or veins. Since normal argillaceous sediments may carry up to 192 grams of copper per ton (Rankama and Sahama, 1950, p. 700), and normal basalts up to 300 p.p.m. of copper (Goldschmidt, 1954, p. 179), and since "copper among sulphide forming minerals has one of the highest affinities for sulphur" (Rankama and Sahama, 1950, p. 696) it would be astonishing if copper were not collected from the geosynclinal tuffs and basalts of the Zeehan Syncline, and surprising if sulphides were not distributed along the Lyell Shear.

The connection between these deposits and those of the lopolithic areas of Michigan is now very clear; the connecting link is simply that in both areas part of the crust has been deeply depressed.

The processes of continual migration of soda and sulphides (and of potash) tend to be independent of zoning and to produce local concentrations, or zones of restricted extent close to faults like the Lyell Shear; but in general the principles of zoning already described still apply.

The final stage of ore genesis at Lyell was related to the late phase formation of the quartz porphyries. Late solutions are presumed to have leached low grade ores at depth and to have precipitated sulphides at higher levels as pipes and veins such as occur at North Lyell and Comstock. Silica carried along in the same solutions, but derived by leaching of silicates, was precipitated as replacements of the chlorite schists around these two bodies and deposited as vein fillings with chalcopyrite, bornite, and gold in the late and north-east tensional fault fissures. The details of a similar late-phase leaching and enrichment of pyritic ores have been set out more fully than this article allows by Lacey (1956). The writer's only comment here is that Lacey's account only touches on very late events which occurred after the formation of pipes like the Blow or the North Lyell bodies. Apart from this difference the principle of late leaching and enrichment is the same.

This account does not aim to discuss ore deposition further but merely to relate rock and ore genesis and this aim is now in part satisfied. Of the other aims listed in the introduction to this work most have been attempted and partly satisfied. Now, at least there is some relation between sulphides and quartz porphyries, and some connection between ores and basalt, and between metamorphism and structure. Further, there is now some direct relation between the ores of the West Coast Range and those of other regions.

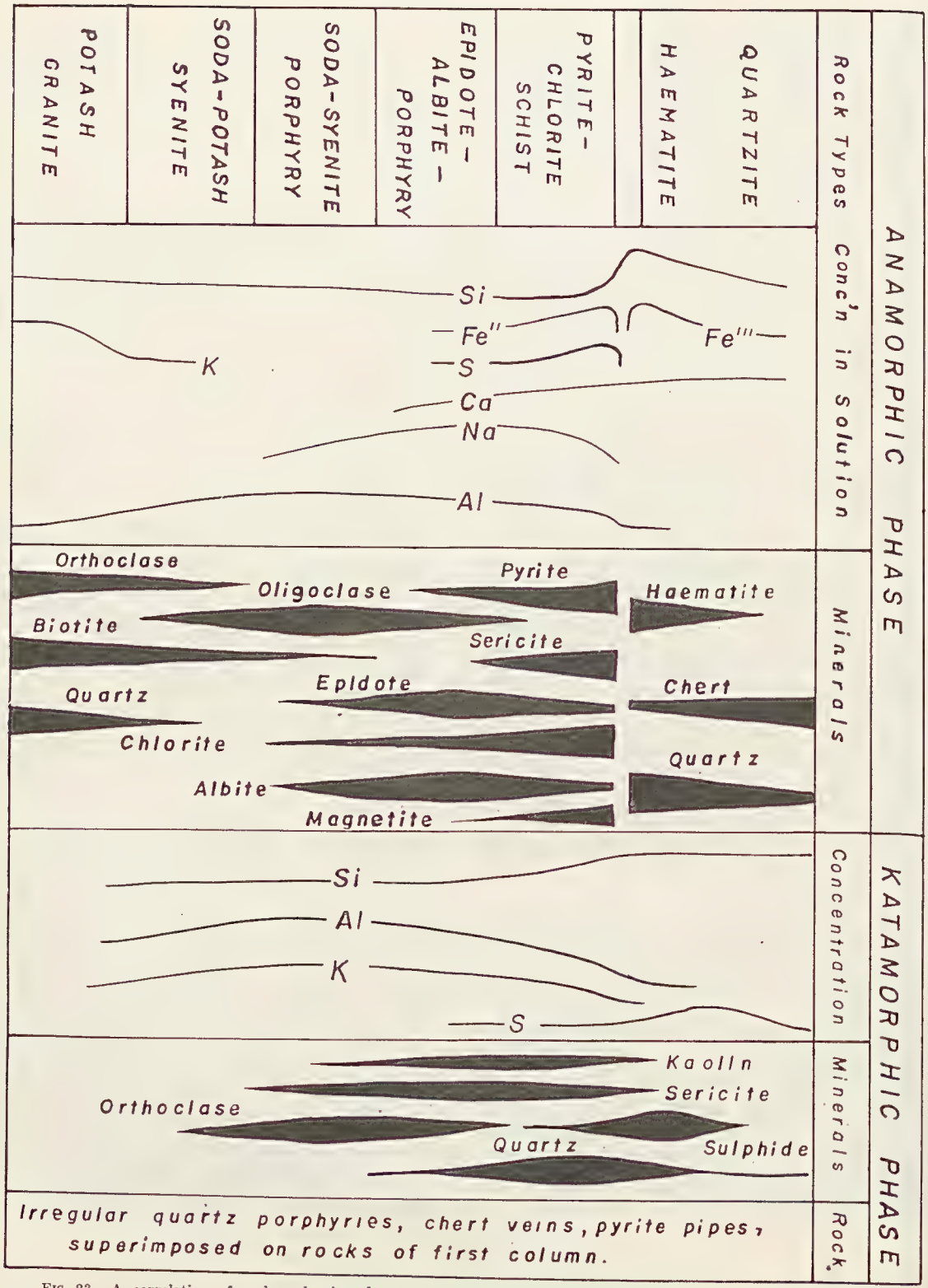

FIG. 23.—A correlation of rock and mineral zones of the West Coast Range with diffusional zones or fronts.

A summary of the account is given in a diagrammatic form in fig. 23 which shows on the left-hand side the zones of rocks and minerals occurring at different depths and their interpretations in terms of relative concentrations of elements in solutions. There is no proportionality between curves for different elements and the curves only express general tendencies. Reading from left to right an upward slope in any one curve implies that the respective element was being taken into solution and a downward slope that the element was being precipitated. Thus the front of aluminium precipitation coincides with a front of sericitising and felspathising, and the zone of resorption of alumina coincides with the resorption of oligoclase.

On the right of the diagram the distribution of minerals and elements in the katamorphic phase is meant to be only suggestive. Thus sulphides, of copper and iron, are usually precipitated above the contact and not below. Kaolinization and sericitising may extend through all the rocks even into otherwise unaltered sediments (for example, at the Sandhill, Queenstown), but are most commonly associated with the felspar porphyries. Similarly orthoclase is not restricted to the zone shown but may extend in thin stringers high up in unaltered Devonian sediments (for example, on High Street, Zeehan). The felspar in all of these cases may be adularia.

In conclusion the writer would draw attention to the findings of Steiner (1953, p. 5) on the results of recent boring for steam in the geothermal district of Wairakei, New Zealand. This is a district of porphyritic ignimbrite rocks and of regional injection by steam along well marked fault lines.

Steiner demonstrates the existence of zones of sulphuric acid leaching (at a depth of 190 feet and temperature of 120°C), argillisation (450 feet, 160°C), zeolitising (600 feet, 160°C), and felspathising (900 feet 220°C). In the outermost zone occurs kaolinising and precipitation of opaline silica; in the next montmorillonitic clays and pyrite are precipitated; in the zeolite zone minor amounts of quartz and albite form; and in the felspathising zona adularia crystallises. The citing of these facts should not be taken to mean that the writer considers that quartz porphyry is now being formed immediately below the bore holes but Steiner's findings undoubtedly provide stimulating food for further thought.

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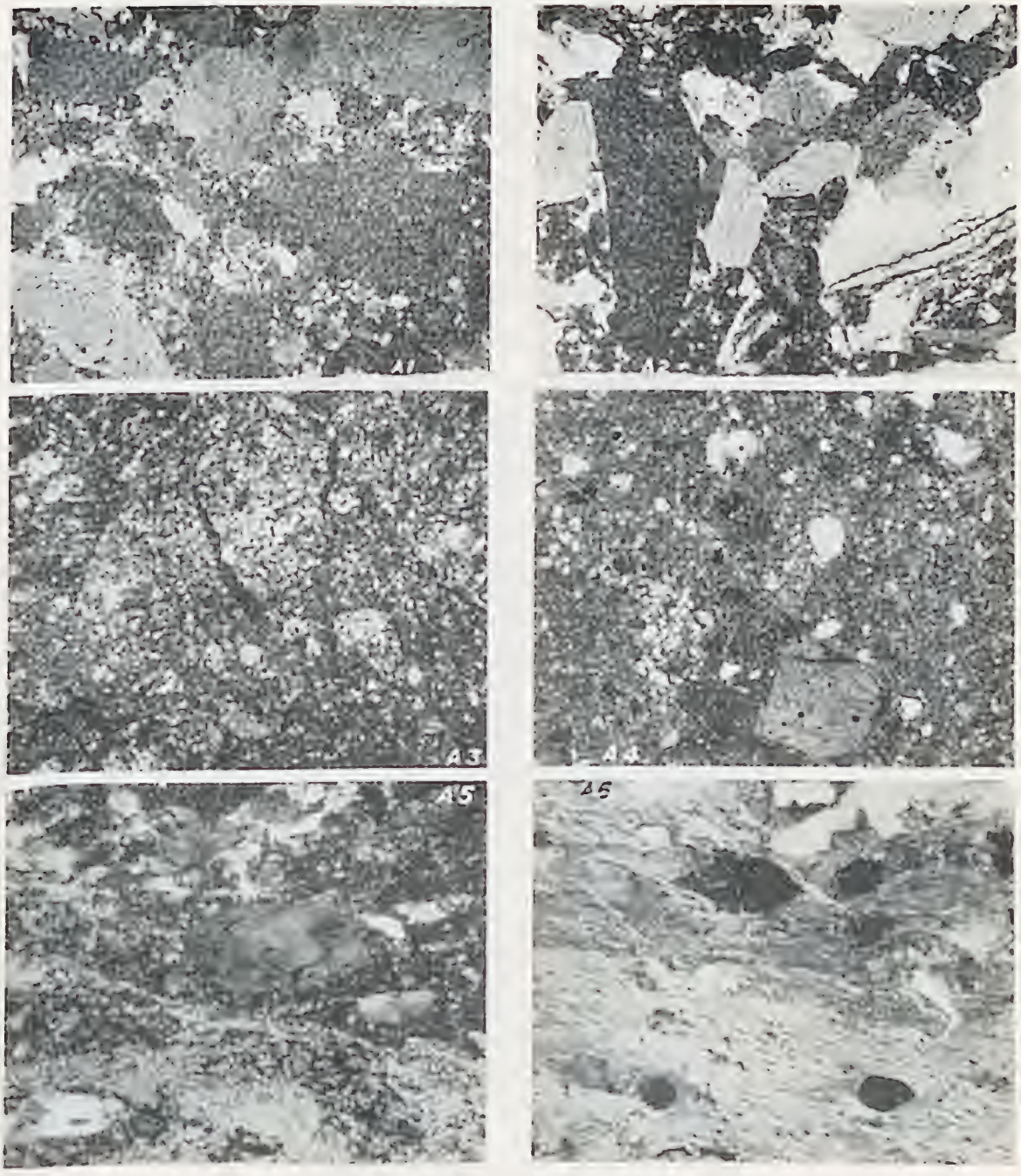
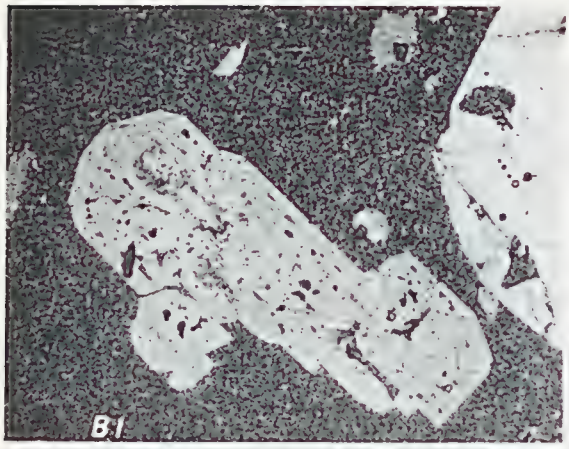


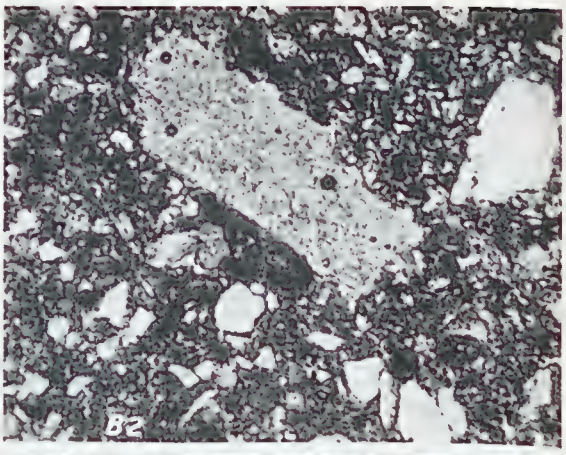
Replacement of the Owen Conglomerate

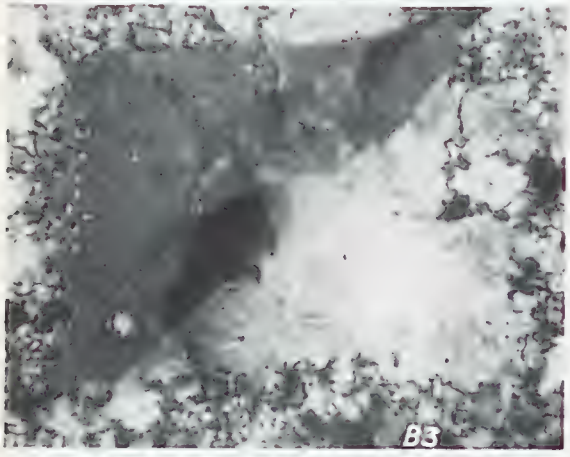
Fig. 1.—Tubicolar Sandstone, West Lyell. Note chert and quartzite pebbles, and matrix of chert and quartz grains; cross nicols: x 20.

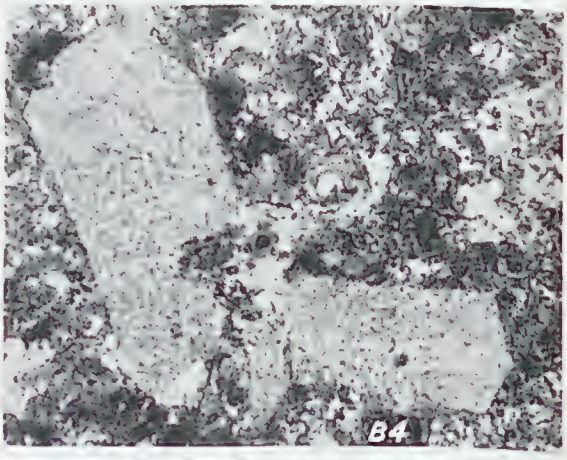
Fig. 2.—Haematised Tubicolar Sandstone, Blow Open Cut. Note preferential replacement of cherty matrix, chert pebbles, and quartzite, in that order; ordinary light: x 20.

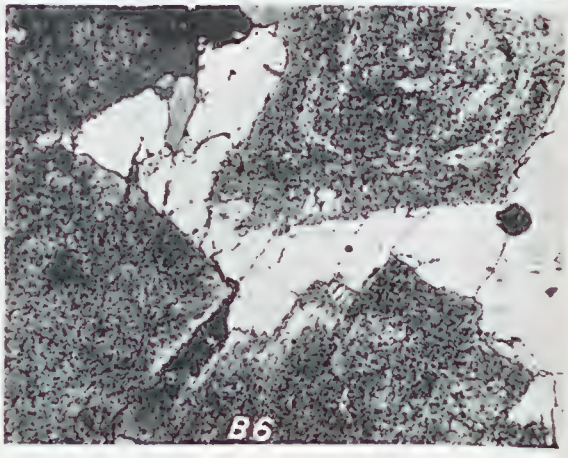
Figs. 3, 4, 5 and 6.—Showing progressive alteration of quartzose Owen Conglomerate to sericite schist. Specimens came from within 2" of the "contact" at Tharsis hogback. White and black lenses represent quartz. The rest is sericite; cross nicols: x 50.











FELSPAR PORPHYROBLASTS

FIG. 1.—Quartz and orthoclase porphyroblasts in fine hornfelsic base, Lake Dora. Cross nicols: x 50.

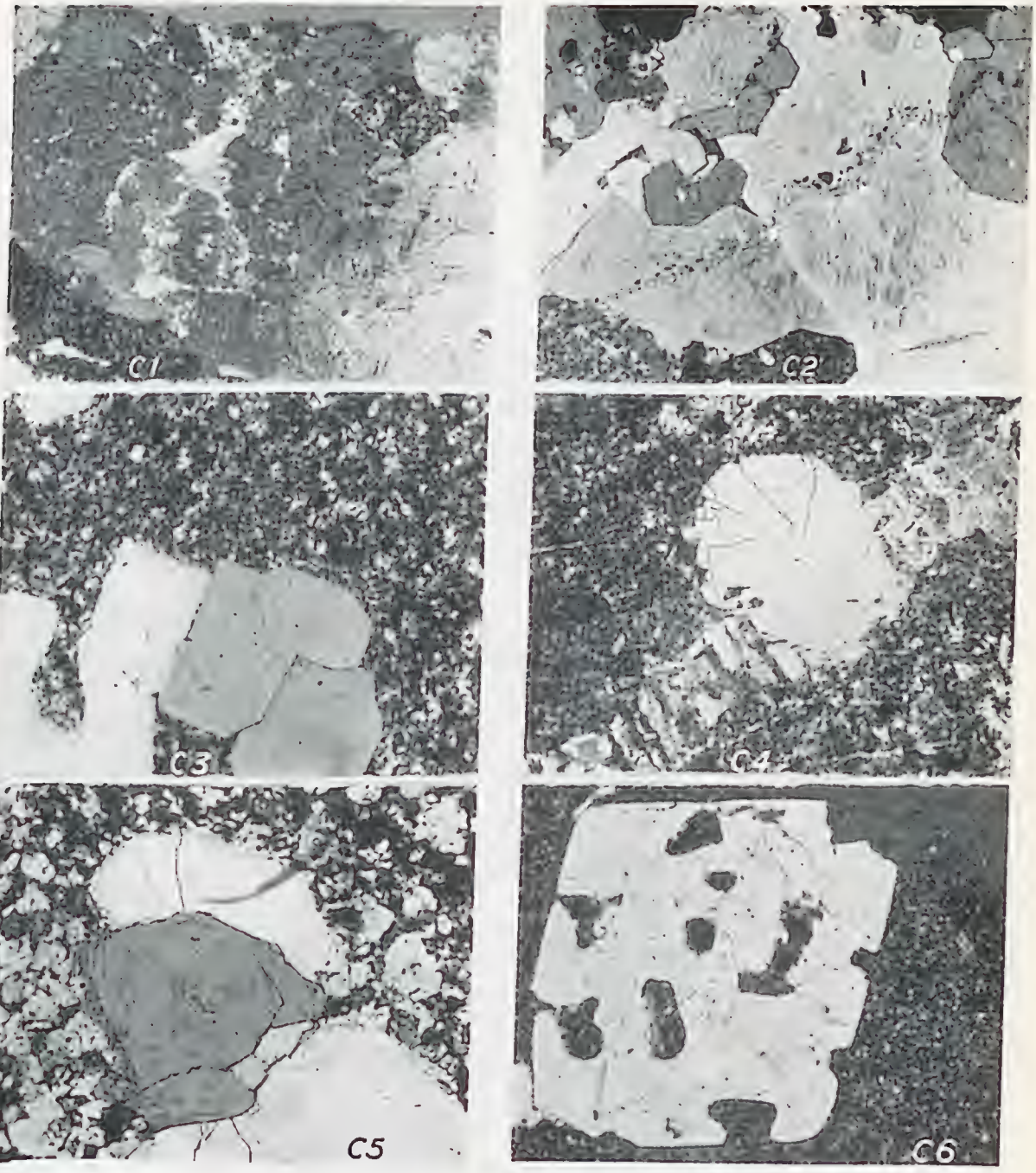
FIG. 2.—Albite in subgreywacke at Lake Julia. Cross nicols: x 50.

FIG. 3.—Orthoclase from Murchison Syenite to show pimply margin. Cross nicols: x 50.

FIG. 4.—Sericitised felspar in Tubicolar Sandstone, Darwin Spur. Cross nicols: x 50.

FIG. 5.—Oligoclase with biotite in felspar porphyry near contact, Lake Dora. Note pimply margin of felspar. Cross nicols: x 50.

FIG. 6.—Orthoclase with ? oligoclase in Darwin Granite. Clear crystal is quartz. The intense sericitising is typical of all rocks. Cross nicols: x 50.



QUARTZ PORPHYROBLASTS

FIG. 1.—Quartz from foot wall of Murchison Mine to show disjunctive extinction. Cross nicols: x 50.

FIG. 2.—Quartz crystals from West Queen River porphyry. The train of inclusions across three crystals shows that crystals have grown in the solid. Cross nicols: x 50.

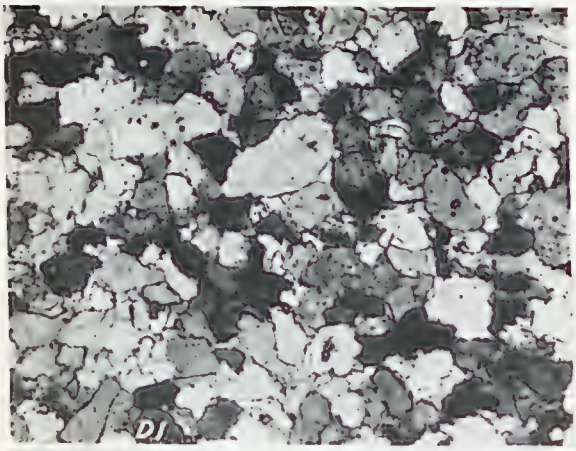
FIG. 3.—Typical quartz porphyry from Roaring Meg Creek on the Queenstown Porphyry body. Cross nicols: x 50.

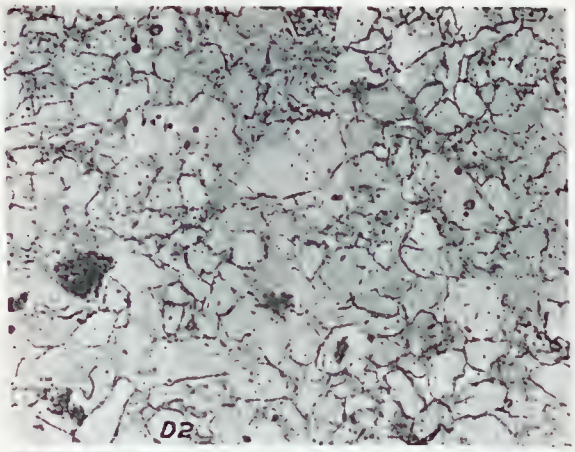
FIG. 4.—Quartz porphyroblast replacing quartz vein replacing hornfels. Tullah Tram. Cross nicols: x 50.

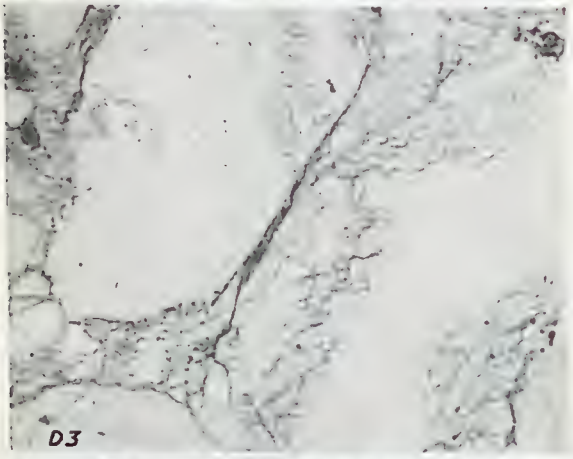
FIG. 5.—Vein quartzite from Mount Bischoff. The porphyroblast has grown in the quartzite by absorbing small crystals. Note margins. Cross nicols: x 50.

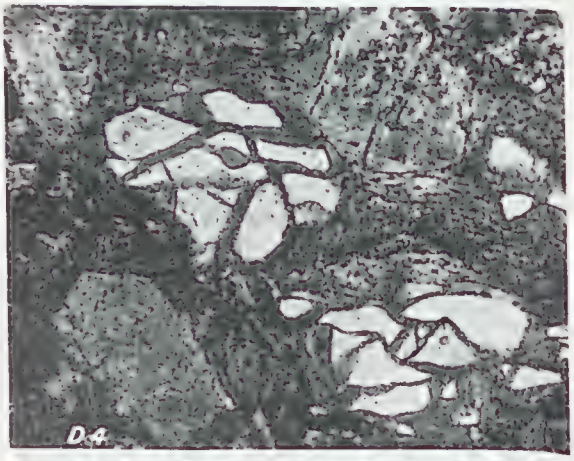
FIG. 6.—Corroded quartz from Lyell Schist. Cross nicols: x 50.

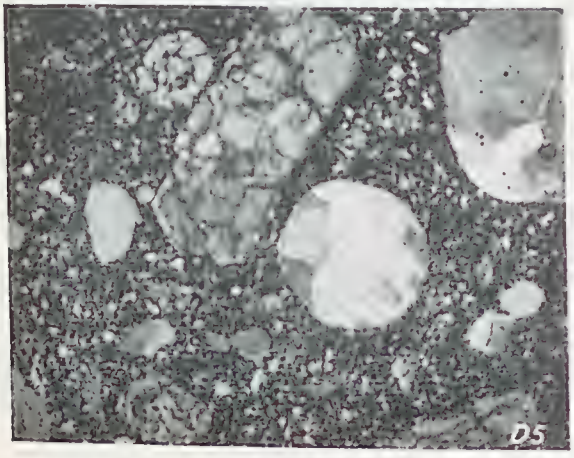
NOTE.—When viewed by means of the universal stage the pimply structures on quartz crystals are seen to extend through the full thickness of the slide and are three-dimensional in form.

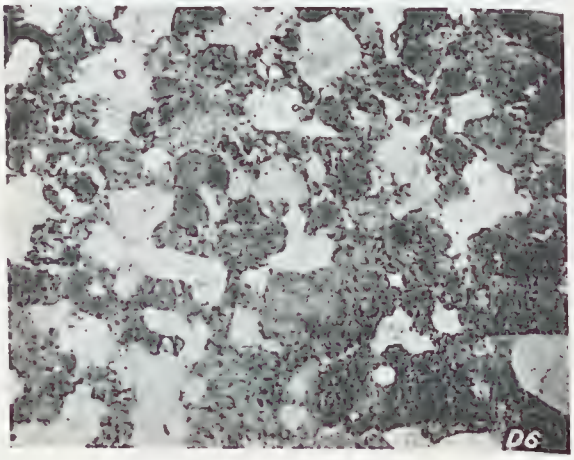












ROCK TEXTURES

FIG. 1.—Tubicolar Sandstone showing apparent angular grains. Cross nicols: x 50.

FIG. 2.—Same field as fig. 1. Original grains are outlined by haematite and were once subangular or round. Some grain growth has occurred and the haematite films have been included in the larger crystals. Ordinary light: x 50.

FIG. 3.—Quartzite pebbles, West Lyell contact. To show replacement of quartzite by haematite along grain boundaries. Ordinary light: x 100.

FIG. 4.—Quartz crystals. The crystals have not been broken and dislocated but have been replaced along fine cracks or strain zones. Note, no quartz particles touch other quartz particles; it is geometrically impossible to fit the particles to form a simple crystal shape; the even width of "fractures" suggests there has been removal of material. Ordinary light: x 50.

FIG. 5.—Typical vesicular basalt, Tullah Track, Rosebery. Large crystal is an augite phenocryst. Clear crystal on mid left is a quartz porphyroblast. Three diffuse crystals along base are sericitised felspar. Vesicle fillings are quartz and calcite. Cross nicols: x 50.

FIG. 6.—Aplite from granite contact, Murchison River. Cross nicols: x 50.

SOME TASMANIAN HIRUDINEA

By

Doris M. Ingram

Department of Zoology, University of Tasmania

(With 61 Figures)

ABSTRACT

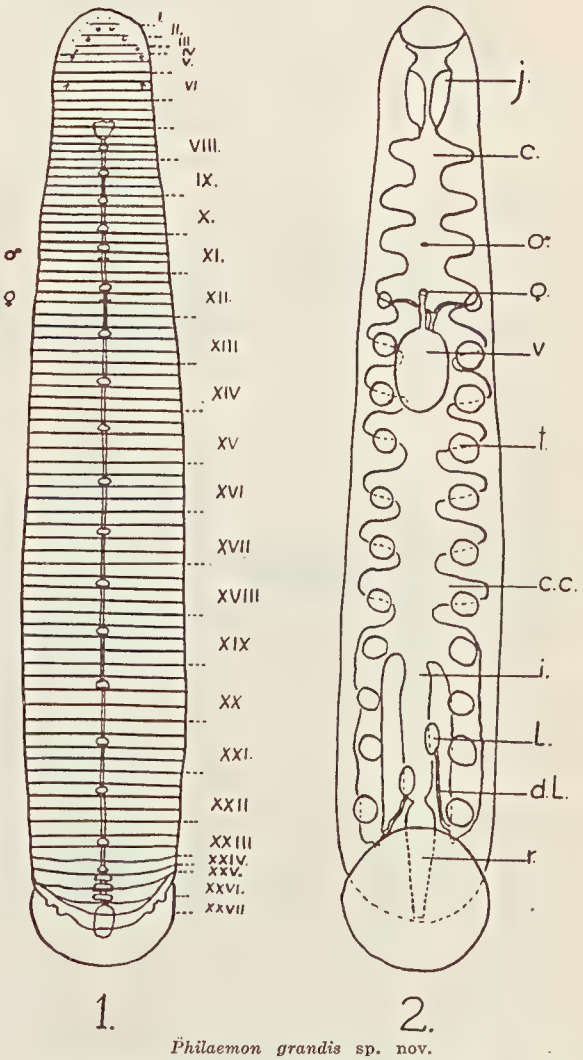
Descriptions are given of two species of Haemadipsidae, one, *Philaemon grandis* sp. nov., the other *Philaemon pungens* Blanchard. The egg-capsule and newly hatched young of the latter species are also described. *Limnobdella australis* (Bosisto) (*Hirudinidae*) is recorded for the first time as occurring in Tasmania. Three new species belonging to the Piscicolidae are also described, namely *Austrobdella bilobata* from *Rhombosolea tapirina* Gunther, *Trachelobdella leptocephali* from the gills of *Leptocephalus conger* (Linnaeus), and "*Ichthyobdella*" *platycephali* from *Platycephalus bassensis* Cuvier and Valenciennes. A brief description of the egg-capsules and young of *Austrobdella bilobata* is also included. In addition, some account is given of specimens of *Branchellion parkeri* Richardson, taken from *Raia lemprieri* Richardson, *Pristiophorus* sp. and *Dasyatis* sp. Further information concerning *Pontobdella tasmanica* (Hickman), its occurrence on a piece of seaweed, and also on a skate, is provided. Three members of the Glossiphoniidae, namely, *Glossiphonia tasmaniensis* sp. nov., *Glossiphonia australiensis* Goddard, and *Placobdella bdellae* sp. nov., are described, the last named species occurring in the buccal cavity of the pouched lamprey *Geotria australis* Gray. The structure of the nephridia in *Glossiphonia australiensis* Goddard is given for the first time.

INTRODUCTION

Three leeches have been recorded previously from Tasmania, namely *Glossiphonia australiensis* Goddard, 1908, *Philaemon pungens* Blanchard, 1898, and *Pontobdella tasmanica* (Hickman, 1942). In the present paper additional records and notes are given on these three species. A new occurrence of *Limnobdella australis* is recorded; an account is given of a Tasmanian example of *Branchellion parkeri;* and the following new species are described:—

1. *Philaemon grandis.*
2. *Austrobdella bilobata.*
3. *Trachelobdella leptocephali.*
4. "*Ichthyobdella*" *platycephali.*
5. *Glossiphonia tasmaniensis.*
6. *Placobdella bdellae.*

Type specimens, some of which are serial sections, are in the Department of Zoology, University of Tasmania.

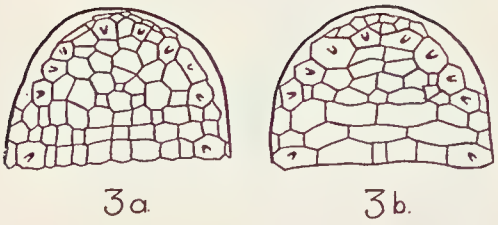


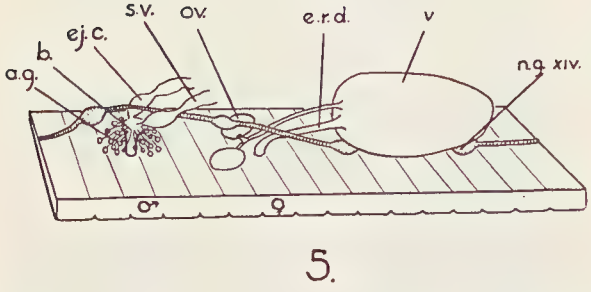
Philaemon grandis sp. nov.

Fig. 1.—Diagram of the dorsal surface of the body. The positions of the ganglia of the ventral nerve cord are shown. The somites (excluding those of the posterior sucker) are numbered I to XXVII.

Fig. 2.—General anatomy, ventral view. The male reproductive ducts are omitted.

c. crop; c.c. crop caecum; d.L. duct of Lambertian organ; i. intestine; j. jaw; L. Lambertian organ; r. rectum; t. testes; v. vagina; ♂. male reproductive aperture; ♀. female reproductive aperture.





Philaemon grandis sp. nov., and *P. pungens* R. Blanchard, 1898

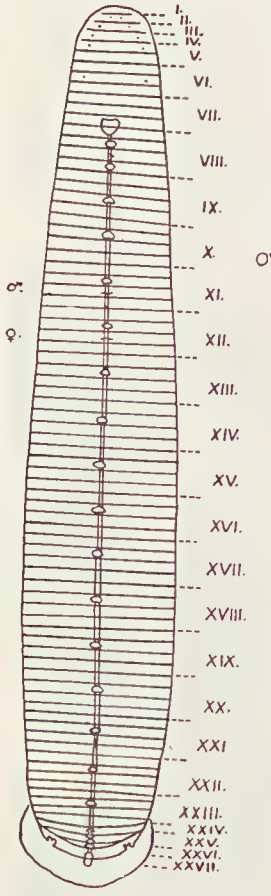
FIG. 3 *a*.—Dorsal view of the head of *P. grandis* showing the irregular arrangement of the tessellae.

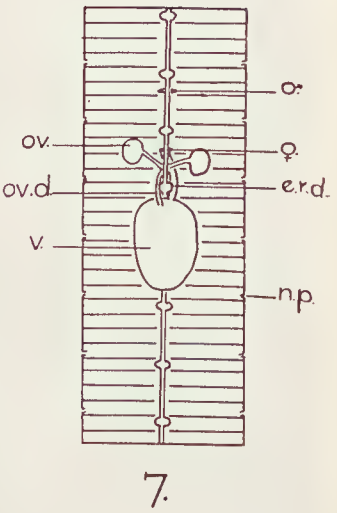
FIG. 3 *b*.—Dorsal view of the head of *P. pungens* showing the regular arrangement of the tessellae.

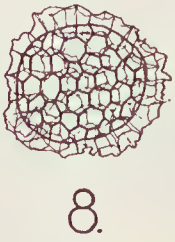
FIG. 4.—Lateral view of the caudal region of *P. grandis* showing the left auricle.

FIG. 5.—Diagram of the reproductive organs of *P. grandis* lying in somites IX to XIV. Only the terminal portions of the seminal vesicles are shown. The testes are omitted.

a.g. male accessory glands; b. bursa; ej.c. ejaculatory horn; e.r.d. external reproductive duct; n.g.XIV. ganglion XIV; o.v. ovary; s.v. seminal vesicle; v. vagina; XXIV. somite XXIV; ♂. annulus bearing male reproductive aperture; ♀. annulus bearing female reproductive aperture.







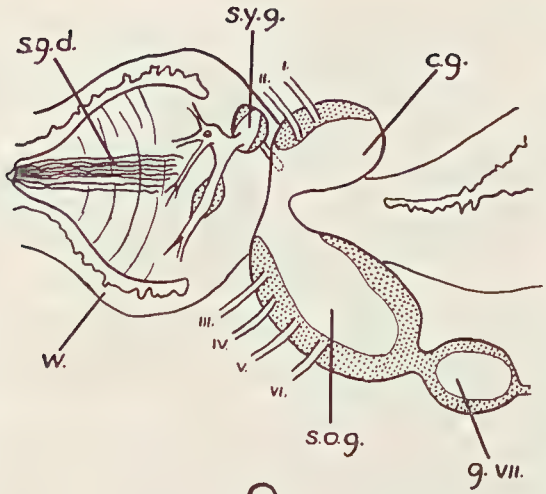
Philaemon pungens R. Blanchard, 1898

FIG. 6.—Diagram of the dorsal surface, showing the somite limits and the positions of the ganglia. The somites (excluding those of the posterior sucker) are numbered I to XXVII.

FIG. 7.—Diagram of the female reproductive organs, in dorsal view.

FIG. 8.—Egg-capsule, drawn from a photograph.

e.r.d. external reproductive duct; n.p. nephridiopore; ov.d. oviduct; v. vagina; ♂. male reproductive aperture; ♀. female reproductive aperture.



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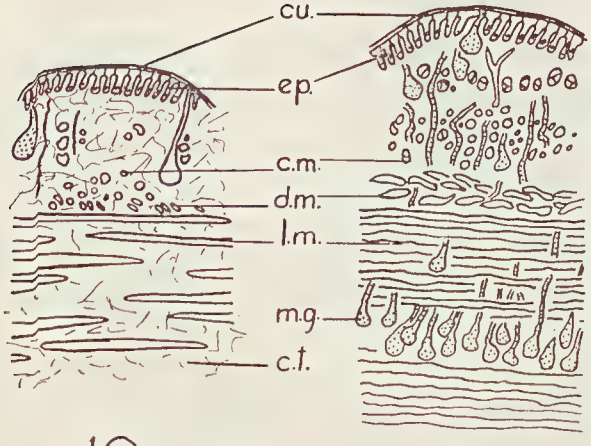


10. 11.

Philaemon pungens R. Blanchard and *P. grandis* sp. nov.

FIG. 9.—Lateral view of the anterior ganglionic mass and the left sympathetic ganglion of P. pungens. The nerves are numbered I to VI.

FIG. 10.—Transverse section of the body-wall of *P. pungens*.

FIG. 11.—Transverse section of the body-wall of *P. grandis*.

c.g. cerebral ganglion; c.m. circular muscles; c.t. connective tissue; cu. cuticle; d.m. diagonal muscles; ep. epidermis; g. VII. ganglion VII; l.m. longitudinal muscles; m.g. mucous glands; s.g.d. ducts of salivary glands in the jaw; s.o.g. sub-oesophageal ganglion; sy.g. sympathetic ganglion; w. wall of pharynx.

Family HAEMADIPSIDAE

Genus **PHILAEMON** R. Blanchard, 1897

DIAGNOSIS EMENDED

Haemadipsidae with the normal somite 4-annulate; 2 denticulate jaws present; auricles present; 10 pairs of testes; Lambertian or posterior organs of the alimentary canal present.

A large species of *Philaemon* occurs in Tasmania and the specific name *grandis* is proposed as being descriptive of its size.

PHILAEMON GRANDIS sp. nov.

(Figures 1-3 *a*, 4, 5, 11)

DIAGNOSTIC FEATURES

P. grandis is a large species of *Philaemon*, first found in western Tasmania. The colour pattern is marked by longitudinal dark stripes. The head-tessellae are numerous and irregularly arranged. The number of rays in the posterior sucker is 76. Somites I-IV are 1-annulate, V is 2-annulate, VI-VII are 3-annulate, VIII-XXIII are complete, 4-annulate, and XXIV-XXVII are 1-annulate. The reproductive apertures are separated by ½+ 3 + ½ annuli, the male being on 27, and the female on 31. Male accessory glands are present. The first pair of nephridiopores opens on the buccal margin between the somites bearing the second and third pairs of eyes, and the last pair opens beneath the auricle lobes; the remaining 15 pairs open laterally on their respective somites. The nephridial vesicles are very large. Posterior or Lambertian organs of the crop are present in somites XXI and XXII.

External Features

The leech measures 36·5 mm. long, 6 mm. wide, and 3 mm. high. The posterior sucker is 5 mm. wide by 4·5 mm. long.

The head region is distinct and rounded. The surface is marked by a tesselated pattern corresponding to the first five annuli. Behind this, distinct annuli are clearly visible. The total number of annuli is 80.

The outer surface of the posterior sucker is tessellated, the areas being small, polygonal, and separated by deep furrows. The inner surface has a central tessellated region from which radiate muscle ridges. These are 76 in number, and are rounded. There are no papillae. The sucker is largely hidden beneath the body.

The anterior sucker is not constricted off from the body, but is a shovel-shaped depression on the ventral surface of the head. At the posterior end of the sucker is a deep buccal cavity at the base of which lies the mouth. This is provided ventro-laterally with two dentate jaws. On the dorsal surface of the head are five pairs of eyes; these belong to somites II, III, IV, V and VI. There is a preocular region constituting somite I. The eyes lie on annuli 2, 3, 4, 5 and 8. The eyes of the third pair are ill-defined, being less heavily pigmented than the others.

Annulus 6 is the first complete annulus. Together with 5, with which it is fused ventro-laterally, it forms the posterior lip of the sucker.

At the posterior end of the body the 77th is the last complete annulus; then follow two incomplete ones. The 78th extends from the ventro-lateral position across the dorsal surface; the 79th annulus is shorter, extending across the region of the auricles. The 80th annulus, on the dorso-lateral borders of which are the auricles, is complete.

The auricles are 3-lobed, flange-like appendages. The middle lobe is small and triangular, and the first and third are larger, with thin membranous margins. The interlobular sinuses are rounded.

The reproductive apertures are separated by $\frac{1}{2} + 3 + \frac{1}{2}$ annuli, the male being on 27, and the female on 31.

Nephridiopores are visible on the caudal borders of the first annulus in somites IX to XXIII inclusive. Thus at first sight there appear to be only 15 pairs of nephridiopores. However, from sections, two additional pairs can be distinguished, the first opening on the buccal margin between the second and third pairs of eyes, and the last opening on the posterior sucker, beneath the auricle lobes.

In living specimens, the dorsal surface of the body has a mid-longitudinal brown stripe. On either side of this are bright yellow patches which are segmentally arranged. In the mid-body region they coalesce, forming irregular longitudinal stripes. On either side of these, and taking up the greater part of the dorsal surface, are brown bands. To the naked eye these appear dark-brown, but under magnification they are seen to be mottled brown and green. The lateral margin of the body is marked by a narrow yellow stripe, which becomes a series of segmental patches in the posterior body region. The ventral surface is a uniform light-brown, as is the marginal part of the outer surface of the posterior sucker.

In preserved specimens, the ventral surface, sides of the body, the entire posterior sucker, the 80th annulus, and the auricle lobes are pale yellow. The dorsal surface of the body is brown, and it is marked by four longitudinal darker-brown stripes in the paramedian and paramarginal positions. The green pigmentation is lost on preservation.

This leech is capable of considerable extension. Three living specimens collected in a gully at Trevallyn had the following lengths (in the resting condition): 5·5 cm., 3·5 cm. and 2 cm. The largest specimen was capable of extension up to about 10 cm. The average distance between successive positions of the posterior sucker, when progressing over a flat surface (a laboratory bench), was 7-8 cm.; the leech moved in a straight line. The medium sized specimen was capable of extension up to about 7 cm., and the average length of one loop was 4-5 cm. The smallest specimen covered a distance of about 3 cm. in each loop.

The characteristic resting position of *P. pungens* is with the posterior sucker attached, either to the base or to the sides of the container, and with the rest of the body free. Specimens of *P. grandis* rarely are seen in this position but most frequently lie under any available cover on the bottom of the container.

Philaemon grandis is not an active leech, the specimens kept in a jar remaining motionless unless touched or blown upon. Unlike *P. pungens*, *P. grandis* soon relaxes into a state of inactivity again.

Internal Anatomy

(*a*) *Body-wall and musculature*: The body is covered externally by a thin cuticle, beneath which is a layer of columnar epidermal cells. These two together form a layer 18μ thick. Among the epidermal cells are mucous gland cells. These are as much as twice as long as the epidermal cells, and project into the sub-epidermal connective tissue layer. Similar gland cells also are found among the muscle layers. They are very numerous in the region of the female reproductive aperture.

The musculature is very well developed. The body wall consists of three sets of muscles, an outer layer 160μ thick, of circular muscles, a middle layer 160μ thick, of diagonal fibres, and an inner layer 250μ thick, of longitudinal muscles. The muscle layers are embedded in connective tissue which extends from beneath the epidermis throughout the body between the various systems.

(*b*) *Circulatory system*: There are three main longitudinal vessels, one dorsal and two lateral. The dorsal vessel is thin-walled and non-muscular; it is derived from the dorsal lacuna. It gives off segmental branches.

The lateral vessels have walls thickened with rings of circular muscles. These vessels have a course which undulates laterally. The lateral vessels give off segmental capillaries, which supply the nephridia. The capillary walls are muscular proximally, becoming less so distally.

The dorsal and lateral vessels are connected anteriorly and posteriorly by capillary networks. A capillary network surrounds the intestine.

The ventral sinus lies in the midventral line. It is almost completely filled by the elements of the central nervous system. The sinus expands segmentally to accommodate the ganglia. The blood is red, and contains phagocytic amoebocytes. These have an average diameter of 8μ, and have a rounded nucleus.

(*c*) *Excretory System*: The excretory system consists of 17 pairs of nephridia, lying in somites VIII-XXIV. The nephridia are similar to those described by Lambert (1898, pp. 228-231) for *P. pungens*. The vesicles are very large, measuring 0·8 mm. long, 0·6 mm. wide and 0·2 mm: deep.

(*d*) *Alimentary Canal*: The mouth lies at the base of the buccal cavity. There are two jaws, ventrolateral in position. The jaws are covered with cuticle which is thickened at the free margin of the jaw, where it forms a row of about 50 denticles. The jaws are highly muscular structures, consisting of circular, dorso-ventral, and longitudinal muscles, the latter a continuation of those of the pharynx.

Running up the centre of each jaw are the ducts of the salivary glands, which surround the pharynx. These glands occur in four paired, ill-defined masses, which are, in relation to the pharynx, postero-ventral, postero-lateral, dorsal and antero-ventral. The ducts from each mass are bundled together and open into the pharynx in the ventro-lateral positions.

The inner surface of the pharynx is marked by three longitudinal ridges, one mid-dorsal and two ventro-lateral. In addition to circular, longitudinal and radial muscles, the pharynx has an external musculature of radiating muscles. These run from the body wall to the pharynx and hold it in position.

The muscular pharynx is succeeded in VII by the short oesophagus. This has thick glandular walls and a poorly developed musculature. The unicellular glands in the oesophageal wall of *P. pungens* are referred to by Lambert (1898, p. 225) as ramose oesophageal glands.

The oseophagus is succeeded in VIII/IX by the crop. This has an epithelial lining, 13μ thick, outside which are a few poorly developed circular muscle fibres. From the crop are given off 11 pairs of caeca, which lie laterally in IX to XIX inclusive. The last pair of caeca is elongated posteriorly, extending to XXIII.

Opening into the posterior caeca is a pair of ducts which run from the posterior or Lambertian organs. These are similar to those found in *P. pungens*, and lie in somites XXI and XXII, the right one anterior to the left. They measure 0·9 mm. long, 0·5 mm. wide and 0·4 mm. deep.

In XIX the main crop canal opens into the intestine. This is lined by a deep epithelium, 50μ thick. Closely associated with the intestinal epithelium is a rich network of blood capillaries. The lining of the intestine is somewhat folded, thus increasing the surface.

The rectum commences in XXII. It is a simple sac, and posteriorly opens to the exterior by the anus which lies behind the last annulus. The lining is an epithelium similar to that of the crop. The rectum becomes muscular towards the posterior end.

(*e*) *Reproductive System*: The male organs consist of 10 pairs of testes which lie intersegmentally in XIII/XIV to XXII/XXIII. The vasa deferentia pass forward and become greatly expanded as the seminal vesicles. The coils of these large thin-walled structures occupy the greater part of the body space in XI to XIII. The left vesicle, which is in XI to XII, is anterior to the right, in XII to XIII.

From the anterior ends of the vesicles, the tubes narrow and become the ejaculatory ducts. The walls of these are well supplied with circular muscle fibres, and are about 50μ thick. The diameter of the ejaculatory ducts decreases as they pass forward.

The two ducts open into the atrium of the bursa. This opens to the exterior by the slit-like male reproductive aperture in the 27th annulus. The bursa is lined by an epithelium, and has muscular walls. Surrounding the terminal portions of the male reproductive system are a large number of pear-shaped, unicellular glands. These have an average length or 30μ and a diameter of 20μ. The cytoplasm is granular, dark at the base, lighter near the duct. The nucleus lies in the dark basal region. The ducts of these glands open between the epithelium cells into the inner part of the bursa.

The female organs are a pair of ovaries lying ventrally in the posterior part of XII, between the seminal vesicles. From each ovary an oviduct passes back, the two oviducts joining in XII/XIII and continuing back as a single duct to the vagina. The duct has muscular walls and is lined by a low epithelium.

The vagina is large, extending from the middle of somite XII to XIII/XIV. In shape, it is ovoid, slightly larger anteriorly. The walls are thick and glandular.

At the anterior end, slightly ventral to the oviduct, is given off a duct which leads to the female reproductive aperture. This duct, referred to in *P. pungens* (Lambert 1898, p. 232) as the external reproductive duct, has very muscular walls, and is lined internally by a somewhat folded epithelium. Both the external reproductive duct and the oviduct are slightly coiled in XII.

(*f*) *Nervous System*: The anterior ganglionic mass lies above and below the pharynx, the two parts being united by connectives on each side of the pharynx. This anterior mass represents six ganglia. The ganglion of somite VII is closely united to the main anterior mass. Ganglia VIII to XXIII are widely spaced, lying in the ventral sinus, and connected by paired nerve fibres. Ganglia XXIV to XXVII have short connectives, and form an anal concentration. They are united to the caudal ganglionic mass, which consists of a fused mass of ganglia XXVIII to XXXIV.

Slightly median to the pharyngeal connectives and partly concealed by them are a pair of small ganglia located on the dorso-lateral surface of the pharynx. They are united by circumpharyngeal connectives, give off bundles of nerve fibres, and are the sympathetic ganglia.

Affinities

Philaemon grandis is closely related to *P. pungens*. A comparison of the two species is given in Table I.

The two species differ in the arrangement of pigment. *P. pungens* has a light mid-dorsal line between dark-brown lateral areas. On either side of the mid-line are light-greenish patches outlined in very dark-brown. *P. grandis* is much paler in general pigmentation and has four longitudinal dark lines.

TABLE I

Comparison of *Philaemon pungens* R. Blanchard, 1898 and *P. grandis sp. nov.*

Character	*P. pungens*	*P. grandis*
Size	12 mm. x 3 mm.—25 x 4	36 mm. x 6 mm.
Number of rays in posterior sucker	58-60	76
Head tessellae	Few, regular	Numerous, irregular
Position of first pair of nephridiopores	Between the annuli bearing third and fourth pairs of eyes	Between the annuli bearing second and third pairs of eyes
Male accessory glands	Absent	Present
Female reproductive ducts	External reproductive duct dorsal to oviduct	External reproductive duct ventral to oviduct
Body wall muscles	Weakly developed	Very well developed

Distribution

P. grandis was first discovered at Temma on the west coast (one preserved specimen). Three other specimens were found at Trevallyn (three living), and two others have been collected but the locality not recorded.

PHILAEMON PUNGENS R. Blanchard, 1898

(Figures 3 *b*, 6-10)

DIAGNOSTIC FEATURES (Blanchard, 1917, p. 653)

'Somites I-III monomères; somites IV-VI trimères; somites VII-XXI normaux, tétramères; somite XXII également tétramère, les anneaux 2 et 3, se fusionnant partiellement sur les côtés de la face dorsale; somites XXIII-XXVI monomères. Nombre total des anneaux: 78. Pores sexuels séparés par quatre anneaux, l'orifice mâle percé en arrière du somite X (anneau 26), la vulve s'ouvrant en arrière du deuxième anneau du somite XI (anneau 30). Pores néphridiaux sur les parties laterales de la face dorsale. Mâchoires portant chacune environ 70 dents.'

Description

The Tasmanian specimens are very similar to those described by Lambert (1898) but show some minor differences. The relative positions of the female ducts are slightly different. In the Tasmanian specimens the external reproductive duct arises from the vagina in a position which is ventral to the point of entry of the oviduct. In the Mainland specimens it is described as being dorsal. The vagina is more anterior in the Tasmanian specimens.

The seminal vesicles are not so large in the specimen sectioned as in Lambert's specimen. This feature, however, is variable, as comparison with compressed whole mounts shows that they may attain quite a large size.

The marginal lip organs are very well-developed. Since these receive a separate nerve supply it is possible that they represent the sensory organs of a preocular somite, such as is recognized by Moore (1927) in *Haemadipsa* Tennent. If this is so, then the anterior ganglionic mass consists of 6 fused ganglia, instead of 5, making a total for the whole body of 34. This agrees with the number recognized in recent works.

In the Tasmanian specimens the anterior ganglionic mass lies further back in the body than it does in those described by Lambert. In the mainland specimens it lies in the 7th to the 9th annuli, while in the specimens before me it lies in the 12th to the 14th.

The sympathetic ganglia lie dorso-laterally on the pharynx-wall slightly anterior to the nerve fibres which pass on either side of the pharynx and unite the dorsal and ventral ganglia of the anterior ganglionic mass. From the sympathetic ganglia, which are themselves united by circum-pharyngeal connectives, nerve fibres are given off to the anterior part of the alimentary canal.

The posterior organs of the alimentary canal lie in somites XX, and XX/XXI. They measure 0·6 mm. long, 0·5 mm. wide and 0·4 mm. deep. The folded nature of the walls is difficult to see as the organs are filled with a granular secretion.

Egg Capsules: Egg capsules have been described for other members of the Haemadipsidae, but not for *Philaemon*. An egg capsule belonging to *P. pungens* was collected at Tarraleah on the 6.1.1954. In general structure it resembles that of *Haemadipsa* Tennent. The capsule is approximately spherical, measuring 7 mm. in diameter. It is pale-yellow in colour. Two regions may be distinguished, an inner capsule with a wall which is entire except for a small aperture at one end through which the young escaped, and an outer region. The outer region is a honey-comb like structure arising from the inner capsule. It consists of about 100 polyhedral cells, open at the outer end. Many of the cells are irregularly hexagonal.

Thirteen young leeches emerged from the capsule. They were very slender, and measured about 5 mm. long. The first emerged on the 20.1.1954, and by the 4.3.1954, all had emerged. When the first emerged, there was no definite colour pattern, the young leech appearing a uniform dark-brown colour. At the end of about three months the colour pattern of *P. pungens* was evident. The young leech now measured 6 mm. long and 2 mm. wide; it was capable of extension up to 15 mm. long. No food was taken until the 11.3.1954, when the leeches were induced to suck the blood of a small frog, *Crinia signifera*.

Distribution

P. pungens is recorded by Lambert (1898, p. 211) as occurring in gullies in various parts of Victoria, N.S.W., and the Western Tiers, Tasmania. Blanchard (1917, p. 653) records it from Victoria, N.S.W., and Java. The specimens referred to in this paper were collected from the following localities in Tasmania:—

1. Ferndene, near Penguin.
2. Junction of Gould's Country and Pyengana roads.
3. Mount Wellington, several localities.

The species also occurs in the far south at Catamaran, and in the North-west, in the Denny Gorge.

Family HIRUDINIDAE

Sub-family MONISTICHODONTA

Genus **LIMNOBDELLA** R. Blanchard, 1893

GENERIC DIAGNOSIS

Size medium to large. Colour pattern usually longitudinally striped, but occasionally spotted or solid. Eyes five pairs, well-developed. Somites IX-XXIII or XXIV 5-annulate and complete. Male and female gonopores very constantly at XI and XII b5/b6. Differs from *Macrobdella* in lacking copulatory glands, and from *Whitmania* in that somite VI is 3-annulate. Jaws small, armed with strong teeth.

LIMNOBDELLA AUSTRALIS (Bosisto, 1859)

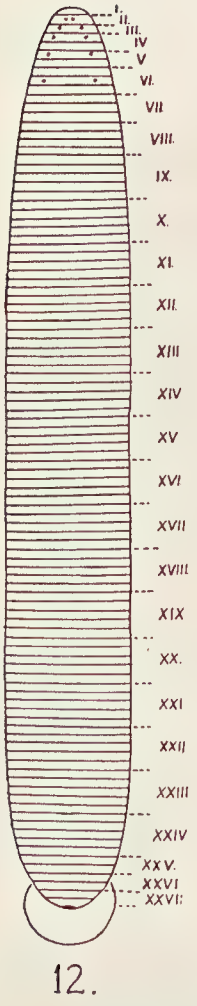
(Figures 12-14)

Leeches referable to this species occur on the west coast of Tasmania. The specimen from which the following description of the external features was made, was collected near the Pieman River.

External Features

(*a*) *Size*: The total length is 52 mm. The maximum width is 5 mm. The posterior sucker is 3 mm. wide, and 2·5 mm. long.

(*b*) *Shape*: The body of the leech is elongated and sub-cylindrical; it is slightly depressed in the mid-body region. Here the sides of the body are sub-parallel, but converge markedly towards the ends.



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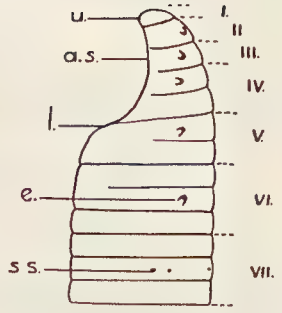

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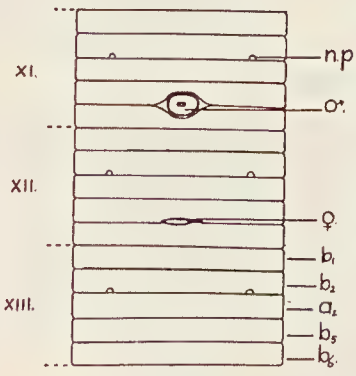

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Limnobdella australis (Bosisto, 1859)

FIG. 12.—Dorsal view of the entire animal, showing the somite limits. The somites are numbered I to XXVII (excluding those of the posterior sucker).

FIG. 13.—Diagram of the lateral part of the anterior end of the body.

FIG. 14.—Diagram of the ventral surface of the body in the clitellar region.

a2. sensory annuli; a.s. anterior sucker; b1, b2. presensory annuli; b5, b6. post-sensory annuli; e. eye; l. lower lip of the anterior sucker; n.p. nephridiopore; s.s. segmental sensilla; u. upper lip of the anterior sucker; ♂. male reproductive aperture; ♀. female reproductive aperture.

At the anterior end are a number of incomplete annuli which form the anterior attachment area. The mouth lies slightly behind the middle of this.

At the posterior end of the body is a small, shallow, cup-shaped sucker. It is centrally attached and has a postero-ventral aspect.

(*c*) *Colouration*: The specimen was fixed in Bouin's Fixative and preserved in 90 per cent alcohol. The dorsal aspect of the leech is brown, marked by a darker longitudinal streak. The ventral surface is slightly paler than the dorsal. The colour of the living leech is reported to be very similar.

(*d*) *Annulation*: The total number of annuli is 103. The first five of these are incomplete ventrally, and form the anterior sucker. The 6th is the first complete annulus, and, together with the 7th, with which it is fused ventrally, it forms the lower lip of this sucker. The 6th and 7th annuli are distinct dorsally, as are the 8th and 9th, which also are fused ventrally.

Three pairs of tubercles are present on the dorsum of 12, 15, 20, 25 and 30. Behind this region they are not apparent, and so are of little help in determining somite limits. The most useful structures for this are the nephridiopores, the genital apertures and the eyes.

Five pairs of well-developed eyes are present, one pair on each of annuli 2-4, 6, and 9. The eyes are on an arc at the anterior extremity.

The reproductive apertures are separated by five annuli. The male aperture is at 31/32 and the female at 36/37.

The nephridiopores lie on the 2nd annulus of the somite, there being four complete annuli between two annuli which bear pores. The nephridiopores lie in paired rows in the ventral paramarginal position. They lie near the caudal border of the annulus.

Goddard (1909, p. 480) gave the following table of annulation:—

TABLE II

Somite	Annuli	Nature
i	1	Uniannulate
ii	2	Uniannulate
iii	3, 4	Biannulate
iv	5, 6	Biannulate
v	7, 8, 9	Triannulate
vi	10, 11, 12	Triannulate
vii	13, 14, 15, 16	Tetrannulate
viii-xxiii	17 . . . 96	Pentannulate
xxiv	97, 98	Biannulate
xxv	99, 100	Biannulate
xxvi	101, 102	Biannulate

Expanding this a little, we have:—

Somite	Annuli	Nature
viii	17-21	Pentannulate
ix	22-26	Pentannulate
x	27-31	Pentannulate
xi	32-36	Pentannulate
xii	37-41	Pentannulate

Now Goddard (1909, p. 482) says that the male and female reproductive apertures are at 30/31 and 35/36 respectively. This, according to the above table, means that they are in X and XI b5/b6. However, in the diagnosis of the genus to which he assigns his specimens, it is stated that the genital

pores are as in Hirudo, i.e., in XI and XII b5/b6. The following modification of Goddard's table, based on the recognition of a preocular somite, fits the diagnosis more closely:—

TABLE III

Somite	Annulus	Nature
i	1	Uniannulate
ii	2	Uniannulate
iii	3	Uniannulate
iv	4, 5	Biannulate
v	6, 7	Biannulate
vi	8, 9, 10	Triannulate
vii	11, 12, 13	Triannulate
viii	14-17	Quadriannulate
ix	18-22	Quinqueannulate
x	23-27	Quinqueannulate
xi	28-32	Quinqueannulate
xii	33-37	Quinqueannulate
xiii-xxiv	38-97	Quinqueannulate
xxv	98-99	Biannulate
xxvi	100, 101	Biannulate
xxvii	102, 103	Biannulate

The annulation is well defined, except on somites I-III, which are uniannulate.

In his description of *L. australis* var. *mauiensis* (originally *Hirudo mauiana*) Benham (1907, p. 185-191) did not recognise a preocular annulus; instead he counted annulus 4 as a separate somite. This method is not used by other workers.

(*e*) *External Openings*: These are of three kinds:—

i. alimentary;
ii. nephridial; and
iii. reproductive.

1. *Alimentary*: The mouth lies near the base of the anterior sucker. Since the anterior somites are turned in, the exact nature of the mouth is difficult to determine. However, three pairs of jaws appear to be present. The anus lies on the caudal border of the last annulus.

2. *Nephridial*: In the specimen before me, 14 pairs of nephridiopores are easily visible. They are situated in two lines on the ventral surface, midway between the mid-ventral and lateral positions. The openings occur on the caudal borders of annuli 29, 34, 39, 44, 49, 54, 59, 64, 69, 74, 79, 84, 89, and 94. The three anterior pairs, i.e., those belonging to somites VIII, IX and X, are not visible.

3. *Reproductive*: The male and female reproductive systems open separately to the exterior by reproductive apertures situated in the mid-ventral line. The male pore opens between annuli 31/32, and the female, between annuli 36/37. The male aperture is distended into the form of a large rounded hole by the penis; the female aperture is a simple, transverse slit.

Distribution

Specimens of *Limnobdella australis* have been recorded, under a variety of names, from several mainland localities. The species is represented in New Zealand by the variety *mauiensis*. The previously recorded localities are as follows:—

1859	? Victoria	*Hirudo australis* Bosisto
1859	? Victoria	*H. medicinalis* Becker
1861	N.S.W.	*H. quinquestriata* Schmarda
1871	N.S.W.	*H. novemstriata* Grube
1893		*L. quinquestriata* Blanchard
1901	Australia	*Limnobdella australis* Brandes
1904	Upper Yarra, Vic.	*L. quinquestriata* Kershaw
1907	Auckland, N.Z.	*H. mauiana* Benham
1909	N.S.W., Victoria, Queensland	*L. australis* Goddard
1911	S.W. Australia	*H. australis* Johanson
1947	Australia	*H. (L.) australis* Parker & Haswell
1949	New Zealand	*L. australis* Richardson

The specimen in my possession was collected on 31.12.1953 in the region of lagoons north of the Interview River (12 miles north of the Pieman River).

Family PISCICOLIDAE

Genus **AUSTROBDELLA** Badham, 1917

GENERIC DIAGNOSIS

'Small marine leeches with well-defined neck and body regions. The body cylindrical in the young, but much flattened in the adult. The lateral parts of the body below the clitellum bulging out and forming a shoulder-like appearance. Somite of six annuli. No pulsating vesicles, their place being taken by a continuous contractile lacuna placed on either side outside the body musculature. Dorsal and ventral median lacunae present, communicating by segmental lacunae. Three pairs of pouches present in the thick-walled intestine, a fourth pair being represented by a flexure in the gut. Testes five pairs. Eyes one pair.' (Badham, 1917.)

Type: *A. translucens*, Badham, 1917.

AUSTROBDELLA BILOBATA sp. nov.

(Figures 15-22)

DIAGNOSTIC FEATURES

A. bilobata resembles *A. translucens* Badham in generic features, but shows certain specific differences. The body is cylindrical in the young, becoming flattened in the adult which has a markedly shouldered appearance posterior to the clitellum. The somite consists of three primary annuli, all of which are subdivided, giving a total of six. Pulsatile vesicles are absent, their function being performed by lateral contractile lacunae only. The crop has seven sets of paired lateral caeca, the last six pairs of which are double. The thick-walled intestine has three pairs of lateral pouches, and a fourth pair is represented by a flexure. There are no eyes. The gonopores are separated by two annuli. The female reproductive system has paired short ovaries without prolonged posterior lobes. There are five pairs of testes. The size of *A. bilobata* is, both in immature and mature forms, greater than that of other described species.

External Features

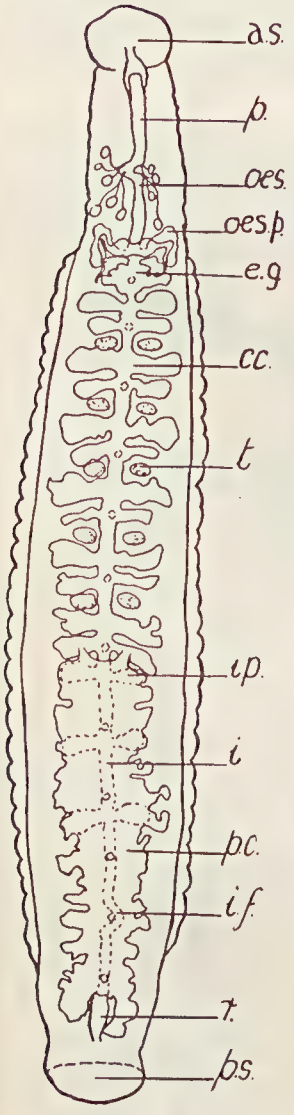
(*a*) *Size and Shape:* The leech is flattened in the urosomal region, and has anteriorly a more cylindrical neck or trachelosome. The distinction between these two regions is less marked in young forms, as shown in figure 19, which represents a series of outline drawings of specimens of different sizes. Table IV gives the measurements of 25 specimens.

(*b*) *Colouration:* The leech is strongly pigmented and shows up distinctly on the surface of the host. The most obvious pigment is dark bluish-black arising from numerous closely-packed stellate cells. This pigment is more concentrated on the dorsum and on the outer surfaces of both suckers. The ventral surface of the living animal appears almost as dark as the dorsal owing to the semi-transparent nature of the leech. However, in killed specimens it is paler. The inner surfaces of both suckers also are paler.

Scattered among the dark pigment cells, and especially along the body margins are reddish-yellow pigment cells. Eyes are lacking.

(*c*) *Annulation:* This is difficult to make out in the living specimen and can best be seen from compressed whole amounts and sagittal sections.

The primary number of annuli constituting a somite appears to be three but, as previously mentioned, in the urosomal region all annuli are secondarily furrowed so as to give the appearance of six annuli per somite.



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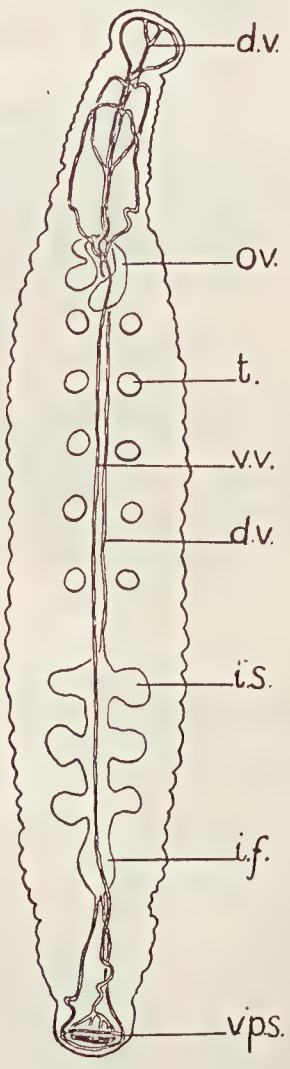

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Austrobdella bilobata sp. nov.

FIG. 15.—General anatomy from the ventral surface.

FIG. 16.—Blood-vascular system from the ventral surface.

a.s. anterior sucker; c.c. crop caecum; d.v. dorsal blood-vessel; e.g. anterior endodermal gut; i. intestine; i.f. intestinal flexure; i.p. intestinal pouch; i.s. intestinal sinus; oes. oesophagus; oes.p. oesophageal pouch; ov. ovary; p. proboscis; p.c. posterior caecum of crop; p.s. posterior sucker; r. rectum; t. testis; v.a.s. blood-vessels of the anterior sucker; v.p.s. blood-vessels of the posterior sucker; v.v. ventral blood-vessel.

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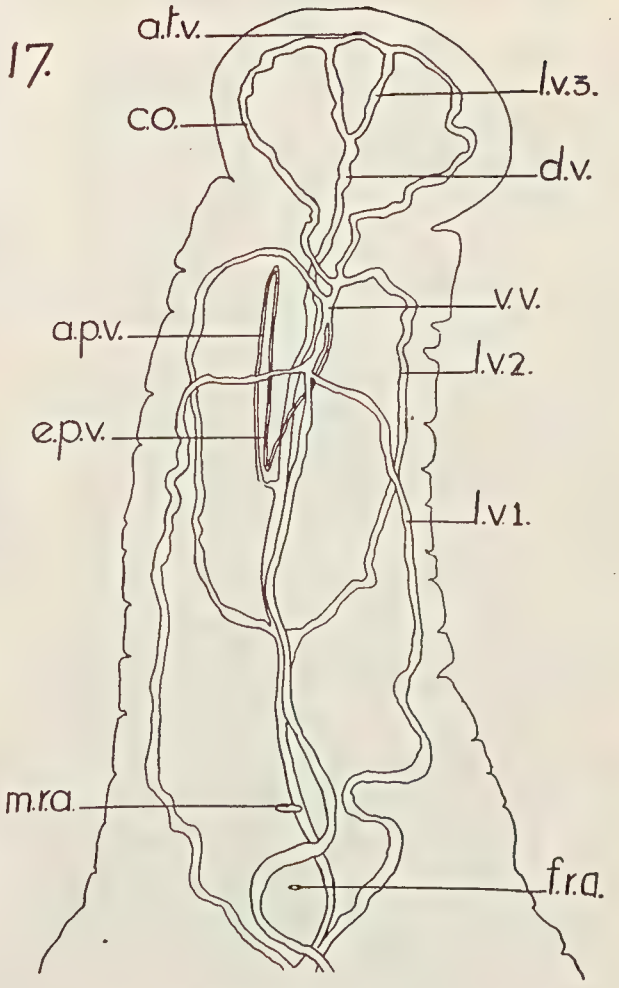


Austrobdella bilobata sp. nov.

FIG. 17.—Diagram showing the main blood-vessels of the trachelosome, as seen in ventral view.

a.p.v. afferent proboscis vessel; a.t.v. anterior transverse vessel, connecting the two limbs of the third pair of lateral vessels arising from the dorsal vessel; c.o. continuations of the third pair of lateral vessels around the anterior sucker to the ventral surface; d.v. dorsal vessel; e.p.v. efferent proboscis vessel; f.r.a. position of female reproductive aperture; l.v.1. first pair of lateral vessels; l.v.2. second pair of lateral vessels; l.v.3. third pair of lateral vessels; m.r.a. position of male reproductive aperture; v.v. ventral blood-vessel.

TABLE IV

Measurements in mm. of *Austrobdella bilobata* sp. nov.

Total length	Maximum width	Diameter of posterior sucker	Length of neck and clitellum	Width of neck
6	0·5	0·5	2	0·5
8	1·5	1·5	2·5	1·5*
9	2	1·5	3	1·5
9	2	1·5	2·5	1·5
9·5	2	2	3	1·5*
9·5	2·5	1·5	3	1·5
9·5	2·5	1·5	3	1·5
10·5	2	1·5	3	1·5
10·5	2	1·5	3	1·5
11	2	1·5	3	1·5
11	2·5	1	4	1·5
12	2·5	2	4	1·5
13	3	2	4	1·5
14	3	2	3·5	2
14·5	3	2	4·5	2
15	3	2	4	2
16	3	2	5	1·5
16	3	1·5	4	2*
16	3	2	5	2
16	3	1·75	4	2
16·5	3·5	2	4	2
18	3	1·5	4	2*
21	4	2	5	2
30	5	2	6	2*
32	5·5	2·25	6	2

* Indicates compressed specimen.

The secondary furrows which divide the annuli transversely at the middle are not so deep as the primary furrows. The ganglia of the nerve cord lie at about the mid-point of the original annulus.

The annulation of the preclitellum and clitellum is not the same as that described above for the urosome, but is of a reduced type. The preclitellum contains 14 primary annuli, the clitellum five, and the urosome 39 plus three incomplete annuli. Of these the last three are ventrally indistinguishable from the sucker. These annuli are nearly all double with the possible exception of the posterior ones. The five clitellar annuli are not subdivided. However, when the position of the nerve ganglia is considered, it appears that these are all primary annuli. Ganglia lie in the second and fourth annuli of the clitellum.

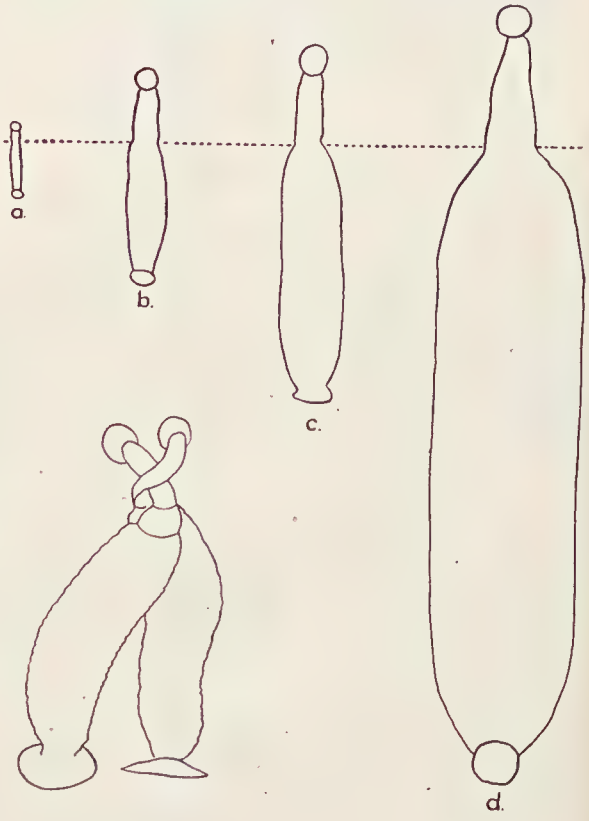
The male genital pore lies on the mid-ventral line between the 2nd and 3rd annuli of XI, and the female pore between the 4th and 5th annuli of XII.

Annuli 9, and 11-14 of the preclitellum are secondarily furrowed.

Internal Anatomy

(*a*) *Bodywall and Musculature:* The body surface is covered by a thin cuticle secreted by the columnar cells of the epidermis. The average height of the epidermal cells is 22μ and the average diameter 6·5μ. The rounded nucleus, which is situated near the base of the cells, has one spherical, usually central nucleolus. Lying among the epidermal cells are scattered gland cells which secrete mucus. These are goblet-shaped, and the main part of the gland lies beneath the epidermis. The depth is of about 39μ, and the maximum diameter 20·8μ. Below the epidermis is a layer of connective tissue, which in turn is underlain by the two muscle layers, an outer circular and an inner longitudinal layer. There is developed in the region of the contractile lacunae, outside the body-wall musculature, a series of large unicellular hypodermal glands. Most have a large central secretion space, and in the adjacent cytoplasm, a deeply straining nucleus. The glands have diameters of up to 82μ.

(*b*) *Coelomic System: A. bilobata* lacks pulsatile vesicles, their place being taken by a pair of contractile lacunae lying laterally outside the body musculature, and extending throughout the length of the urosome. Segmentally they are connected with the rest of the coelomic system by a branch from the segmental lacuna. The normal lateral lacunae are lacking.

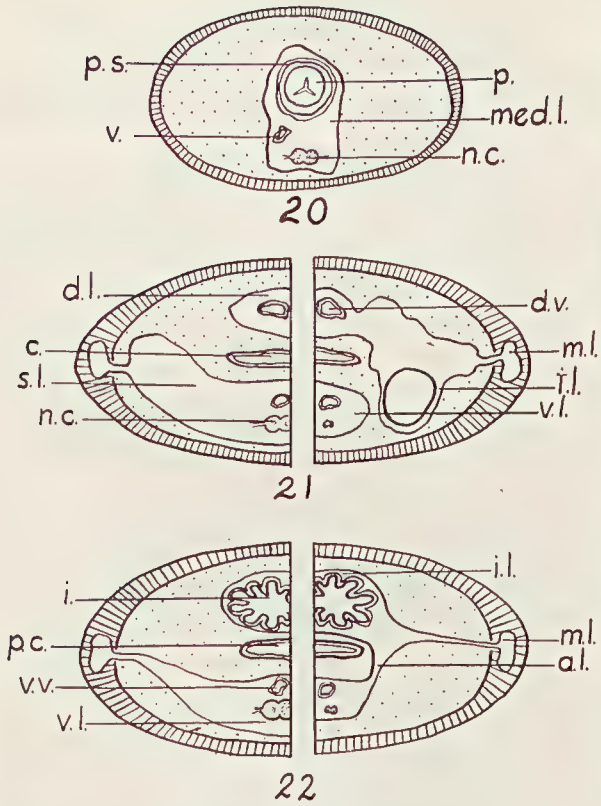


18. 19.

Austrobdella bilobata sp. nov.

FIG. 18.—Two individuals copulating.

FIG. 19.—Outline drawings of four specimens of different size. a. 3 mm. long; b. 8·5 mm. long; c. 13·5 mm. long; d. 30·5 mm. long.
The dotted line marks the division between the trachelosome above and the urosome below.



Austrobdella bilobata sp. nov.

FIG. 20.—Diagrammatic transverse section through the trachelosome. The shaded area lies outside the body-wall muscles.

FIG. 21.—Diagrammatic transverse section through the testis region of the urosome; left side segmentally, and right side intersegmentally.

FIG. 22.—Diagrammatic transverse section through the intestinal region of the urosome; left side segmentally, and right side intersegmentally.

a.l. accessory lacuna; c. crop; d.l. dorsal lacuna; d.v. dorsal blood-vessel; i. intestine; i.l. intestinal lacuna; med.l. median lacuna; m.l. marginal lacuna; n.c. nerve cord; p. proboscis; p.c. posterior crop caecum; p.s. proboscis sheath.

The dorsal lacuna is a well-developed structure. In the anterior part of the body it contains the dorsal blood vessel, and in the posterior part surrounds the intestinal sinus (i.e., the thick-walled intestine with its associated blood space).

The ventral lacuna lies ventral to the alimentary canal, and contains the ventral nerve cord and the ventral blood vessel. Anteriorly it expands, so as to enclose the proboscis and anterior ganglionic mass. It is similarly expanded in the anterior urosome, where it contains the ovaries and testes.

Segmentally both dorsal and ventral lacunae give off branches which unite laterally. From these a short branch runs out through the longitudinal and circular muscles to unite with the contractile lacuna. Dorsal and ventral capillaries are given off from the contractile lacunae.

(c) *Blood-vascular System:* The blood-vascular system is described from one of the paratypes, a compressed whole mount. The preparation was heavily overstained in alum carmine and then slowly differentiated, in 0·6% acid alcohol for a period of about eight hours.

There is a dorsal median longitudinal vessel which anteriorly gives off three pairs of lateral vessels and an unpaired proboscis branch. The posterior pair of lateral vessels arises posterior to the female reproductive aperture, and is directed initially outward, and then forwards and ventral. The second pair arises in somite X and follows a similar course. At its anterior extremity, about midway through the anterior sucker, the dorsal vessel bifurcates. The members of the anterior pair of vessels so formed run towards the edge of the sucker, where they are connected by a transverse vessel. Then they continue around the edge of the sucker and leave it ventrolaterally. These two vessels unite in the region of the anterior ganglionated nerve mass and continue as a ventral median longitudinal vessel. This receives, immediately behind the brain, the ventral anterior continuation of the second pair of lateral vessels given off from the dorsal vessel. The vessels do not enter immediately opposite one another. A short distance behind is the point of entry of the efferent proboscis vessel. The afferent proboscis vessel, after leaving the dorsal vessel, runs forward in the proboscis to about the level of the brain, then turns and continues back parallel to the forwardly directed portion. Near the original point of entry this vessel leaves the proboscis and once more becomes forwardly directed, this time ventrally as well, and unites with the ventral vessel in the abovementioned region.

A short distance posterior to this junction, are the entry points of the antero-ventral ends of the posterior pair of lateral vessels.

The ventral vessel then continues as an unbranched tube to the base of the posterior sucker. Here it splits into a number of branches which run to the more deeply situated of the two concentric ring vessels which lie in the marginal parts of the posterior sucker. This inner ring vessel is connected with the outer ring vessel by a number of short cross branches. From here paired dorsolateral vessels arise and run forward to unite in the mid-dorsal line in the region of the intestinal flexure. Throughout the region of the thick-walled intestine, from the gut flexure posteriorly to the most anterior of the three pairs of caeca anteriorly, the dorsal vessel becomes part of a sinus which surrounds the thick-walled intestine.

Badham (1817, pp. 31-32) has described the circulation of the blood in *Austrobdella translucens*. The blood system of *A. bilobata* differs from that in the type in only minor features, mainly in the anterior region.

(d) *Excretory System:* Excretion takes place by means of 11 pairs of nephridia situated in somites XIII to XXIII inclusive The nephridial tubules are very fine and form a network in the lateral

parts of the body. The internal opening is by a coronet of cilia-bearing cells, into the lateral parts of the ventral lacuna. A ciliated funnel and a capsule are absent.

(*e*) *Digestive System:* The mouth opening is in the middle of the anterior sucker, and leads to the proboscis sheath. This extends back as far as IX, and consists of a thin epithelium covering a thin layer of longitudinal and circular muscles. Within the proboscis sheath is the proboscis, covered externally by an epithelium which is continuous with that of the sheath. Beneath this are the longitudinal, radial and circular muscles of the proboscis. Between the radial muscles are found the ducts of the salivary glands, which discharge at the anterior end of the proboscis. The ducts of the salivary glands enter the proboscis at its base. These glands lie on either side of the proboscis in somites VIII to XI. On either side there are six or seven very large glands of diameter up to 328μ, and a number of smaller glands of diameter 80μ.

The proboscis is followed by a narrow, thin-walled oesophagus. Slightly posterior to the level of the male pore the two lateral ducts of the oesophageal pouches enter the oesophagus. These pouches are considerably expanded and have lobate walls; their openings into the oesophagus are narrow. The oesophagus extends back as far as XII/XIII, where it enters the crop.

This is essentially a straight tube giving rise to seven pairs of lateral caeca. The first pair of caeca, which have very wide openings into the crop, arises from the crop canal at the level of the female reproductive aperture. The pair of caeca occupying the same position in *A. translucens* described by Badham are considered by that author to constitute a separate region, the anterior endodermal gut.

From the following region the remaining six pairs of caeca arise in somites XIV to XIX. Only the anterior two-thirds of the somite is occupied by the pouch, the posterior one-third, in somites XIV to XVIII, being the position in which the testes are found. Each individual pouch is deeply lobed, so that whereas in other recorded species of *Austrobdella* there are simply six pairs of crop caeca in this region, in *A. bilobata* there are 12. Of the two pairs of caeca arising in each somite, the anterior pair is slightly the larger. The condition is shown in figure 15.

Ventrally from the posterior pair of caeca is given off a median diverticulum; this originates as two pouches which fuse along the midline. They are separated for a short distance—about one-seventh of their length—posteriorly. There are five fenestrae.

The median crop canal passes dorsally into the thick-walled intestine. From this three pairs of simple lateral diverticula arise. A possible fourth pair is represented by a flexure in the main intestinal canal. The entire intestinal region is enveloped by the intestinal sinus, which arises from the dorsal blood vessel. The posterior end of the intestine is a straight tube, which narrows posteriorly to the rectum, and becomes directed upwards. It opens in the mid-dorsal line between the 3rd and 4th annuli from posterior end.

No digestive glands apart from the salivary glands and possibly the oesophageal pouches, are associated with the alimentary canal.

(*f*) *Reproductive System:* The leech is hermaphrodite, and apparently protandrous, specimens 6 mm. in length having mature testes and slightly immature ovaries.

The male reproductive organs consist of five pairs of testes alternating with the crop diverticula 2-7 and situated in the last annulus of XIV, XV, XVI, XVII and XVIII respectively. On either side they link up with a longitudinal vas deferens which passes forward to XII-XIII, where it expands and becomes the somewhat coiled ejaculatory duct. Above and lateral to the male reproductive aperture these ducts become the very much enlarged ejaculatory cornua, which unite in the midline into a short muscular spermatophore-sac opening to the exterior at the male pore. Entering the spermatophore-sac or bursa on either side are masses of unicellular "spermatophore" or accessory male glands.

The female system consists of a pair of ovaries lying in the 2nd and 3rd urosomal annuli. The ovaries are asymmetrical in position, the left one being a more or less rounded mass largely confined to two, while the right one is more elongated, extending through two and three, and is closer to the midline. This, however, is not constant, as the arrangement is not the same in all specimens. Other workers have recorded the fact that the ovaries may vary considerably in position in other leeches; so much so that they have been mistaken for hearts in living material. Anteriorly the ovaries lead into straight oviducts which unite in XIII. The single short duct so formed passes forward and opens into the enlarged and glandular chamber. The epithelial lining of this is a continuation of the general body epithelium and is thrown into folds within the pouch. This is surrounded by a cellular connective tissue, such as described by Badham (1917, p. 36) as conductive tissue in *A. translucens*.

Clitellar glands are present within the body-wall musculature and occupy nearly all the space between it and the various systems—alimentary, reproductive and vascular. From the glands the ducts lead forward to open at the clitellum, in somites X-XII. Two kinds of glands may be distinguished. The larger (which in a specimen 18 mm. long had a diameter of 196·8μ) have a large secretion space surrounded by very granular cytoplasm. The secretion space is filled with a finely granular material which stains light-pink with eosin. The smaller glands, of average diameter 82μ, differ from the larger in the nature of their secretion, which stains a vivid pink with eosin.

The ducts are placed in four groups, two dorso-lateral and two ventrolateral.

Copulation: Fertilization takes place by means of spermatophores, which are exchanged during copulation. The process of copulation was observed about 4 p.m. on 29th June, and lasted intermittently over a period of about 10 minutes. Three leeches were involved, although only two copulated at any one time. The specimens were kept in sea water in Petri dishes. The leeches fastened themselves

by means of the posterior sucker on to the bottom of the dish. The free anterior end was then moved actively about until it came in contact with another leech. The necks of the two individuals then became mutually entwined so that the reproductive apertures were adjacent. In this position copulation occurred. The glandular vagina of the female system was at times partly extruded, probably to facilitate the deposition therein of the spermatophore. Strong muscular contractions were observed in the clitellar region. These appeared to have their origin in the ejaculatory coruna, which were considerably swollen, so as to make their outlines clearly visible in macroscopic view.

For some time preceding and following copulation, the leeches were very restless, and agitation of the container caused them to move about actively.

Egg Capsules: These were deposited by a number of leeches kept in sea-water in a glass jar at ordinary room temperature, during the periods 16th-31st March, 11th-13th May, and 25th-30th June, 1954. As soon as the leeches started depositing the capsules, one leech was isolated and kept from 17th March-31st March in a separate container. Over this period it produced 67 capsules, more than half (about 40) being deposited during the first week. The egg capsules were always produced at night, and were deposited on the bottom and sides of the container.

Capsules were deposited by leeches collected on the 15th March, 1954, 7-10th May, 1954, and 25th June, 1954. Five specimens collected on 30th August, 1954, failed to produce any capsules.

The capsules are small (0·8 mm. x 0·65 mm. x 0·50 mm.) translucent amber-yellow structures, which become darker as development proceeds. The lower or attachment surface is flattened and the upper dome-shaped. The wall of the capsule resembles chitin and is slightly elastic. Only one leech hatches from each egg-capsule, and it is about 3 mm. in length when it emerges.

In no case were the egg capsules observed attached to flounders. Under natural conditions the leech probably leaves its host in order to deposit the capsules.

The young *A. bilobata* take 3-4 months to emerge from the capsule. The young leech is semi-cylindrical with both anterior and posterior suckers well-developed. It is but lightly pigmented, the pigment being a light pink as contrasted with the very dark bluish-black of larger specimens.

(*g*) *Nervous System*: This shows no important differences from that described for *A. translucens* by Badham. The ganglia are large and well-developed.

Habits (including Relation to Host)

Austrobdella bilobata is a hardy animal, and can withstand adverse conditions with no apparent disadvantage.

A catch of flounders was made on the 20th June, 1954; some flounders from this catch were placed in a large tub. There was no water in the tub and the fish soon died. Several hours after the death of the fish the leeches adhering to them were found to be still alive and firmly attached. When removed to jars of sea-water they lived for several weeks.

The living leech exhibits several kinds of movements, the most obvious being:—

(1) respiratory;
(2) crawling; and
(3) swimming.

(1) *Respiratory movements:* Respiration is performed by the pair of lateral pulsatile lacunae, which take the place of the pulsatile vesicles of *Branchellion*. When the living leech is observed, waves of undulations can be seen passing along either side of the body, throughout the post-clitellum. A single complete pulsation consists of a wave of contraction starting immediately behind the clitellum and finishing slightly in front of the posterior sucker. When one complete wave is finished, another begins. The contractions take place simultaneously on either side. The rate of contraction is about 19 per minute. When observed in the natural state *A. bilobata* appears very inactive, spending the greater part of the time attached (very firmly) by the posterior sucker to the side of the container, the anterior end of the leech remaining free or loosely attached. If watched closely, the sides of the body are seen to be in continual movement, of the type described above.

(2) *Crawling movements:* When disturbed, the leech moves with a somewhat uncertain looping motion for a short distance. Much time appears to be required for relaxing and renewing the hold of the suckers, especially that of the posterior sucker. When attached to the host, the leech rarely moves from its position.

(3) *Swimming movements:* These were observed only rarely, notably when a leech was detached and released in the water near the top of the tank. The leech, as it sank through the water, exhibited violent rhythmic muscular contractions, which propelled it slowly forward as it sank. It seems probable that such movements would occur only rarely in the natural state for the association of the leech with the flounder is apparently semi-permanent. The leeches remain firmly attached to the flounder even when the latter has been removed from water and is dead. However, the ability to swim is well-developed, even in newly hatched specimens.

Occurrence of A. bilobata *on its host*

Leeches were found on flounders (*Rhombosolea tapirina* Gunther) taken at Pittwater, Tasmania, during April and May, 1954. From a total catch of 296 flounders, 51 specimens of *A. bilobata* were collected. The following table indicates the number of leeches found on each fish.

TABLE V

Occurrence of *A. bilobata* on flounders

No. of Flounders	No of Leeches per Fish
261	0
25	1
8	2
1	3
1	7

With the exception of one leech found on the lower surface near the mouth, all were on the upper surface (i.e., right side morphologically) of the flounder, above the body cavity. It is possible that the specimen on the lower surface was a new infection and that the leech was making its way to the more usual position.

Badham (1917, p. 2) says *A. translucens* which parasitizes the Australian Sand Whiting (*Sillago ciliata*) occurs . . . 'on the fins—pectoral, pelvic, dorsal and caudal; their presence also was noticed around ulcerated patches on the sides of the fish, and a few were found in the proximity of, but not on, the gills'.

The region above the body cavity, as mentioned above, appears to be the only normal site for *A. bilobata;* its presence has never been noticed on the fins. Scars similar to those mentioned for the sand whiting occur above the body cavity in the flounder. They are present even in small specimens of the host.

No host relationships are given for *A. anoculata* Moore.

Relation to Existing Species

A comparison of *A. bilobata* with the two existing species is given in Table VI.

TABLE VI

Comparison of *Austrobdella* spp.

	A. translucens Badham	*A. anoculata* Moore	*A. bilobata* sp. nov.
Maximum length	13 mm.	6·8 mm.	35 mm.
Minimum size recorded	1·5 mm. in length	(No young stages)	2·5-3 mm. in length on emergence from egg capsule
Transparency	Transparent	Semi-transparent	Translucent to opaque
Pigmentation	Pigmentation by means of stellate reddish-brown cells and a number of smaller cells of shades of purple	No natural colour remains, but the type is stained a uniform green, which may be due to preservation in a copper tank	Blue-black, darker dorsally than ventrally with some amber-yellow pigment cells. Pigment cells stellate
Eyes	1 pair present	Absent	Absent
Number of annuli in mid-body normal somite	(3) 6	3 (6)	(3) 6
Division of body into trachelosome and urosome	Marked in adult	Marked in adult	Marked in adult
Oesophageal pouches	Present	Apparently absent	Present
Anterior endodermal gut	Trilobed	Not distinguished	Trilobed
Crop caeca	6 pairs, somewhat lobed distally	Similar to *A. translucens*	12 pairs, equivalent of the 6 in other species
Separation of posterior caecum	About 1/7th of total length free behind	About 1/5th of total length free behind	About 1/7th of total length free behind
Intestinal caeca	3 pairs	2 or 3 pairs	3 pairs
Intestinal flexure	Present	Absent; place taken by an expanded region	Present
Ovaries	With prolonged posterior lobes	Without prolonged posterior lobes	Without prolonged posterior lobes
Oviducal horns	Large	Absent	Absent
Testes	5 pairs	5 pairs	5 pairs
Nephridia	11 pairs	Not recorded	11 pairs
Host	Australian sand whiting, *Sillago ciliata*	Not recorded	Southern or common flounder, *Rhombosolea tapirina* Gunther
Location of parasite on host	The parasites were found on the fins—pectoral, pelvic, caudal and dorsal; present also around ulcerated patches on the sides of the fish	Not recorded	On the upper (right) side of the fish, above the body cavity, where they produce ulcerated patches and extensive scars. Never on the fins

Genus **TRACHELOBDELLA** Diesing, 1850

Generic Features

The body is elongated, and divided into two regions, an interior trachelosome and a posterior abdomen. The former is short and cylindrical, and may bear lateral non-pulsatile vesicles. At its posterior end it becomes slightly expanded as the clitellum. The abdomen is long and may be somewhat depressed. Along its sides are 11-13 pairs of pulsatile vesicles. There are two suckers, both usually rather small, the diameter of the posterior one rarely exceeding the maximum body width. The normal mid-body somite has three primary annuli, each of which is subdivided by a transverse furrow so as to form six. A posterior crop caecum is present. There are five pairs of testes, and the bursa is large and folded. Members of this genus are found, with rare exceptions, as ectoparasites on marine fishes.

Type: *T. mülleri* Diesing, 1850.

A Tasmanian leech which may be assigned to this genus has been found on the gills of the conger eel (*Leptocephalus conger* (Linnaeus)). Table VII gives a comparison of this species with others assigned to the genus, from which it appears to be distinct. The specific name *leptocephali* is proposed for it.

TRACHELOBDELLA LEPTOCEPHALI sp. nov.

(Figures 23-28)

Diagnostic Features

The body is of moderate size, much larger in the urosome than in the trachelosome. The urosome has 13 pairs of lateral pulsatile vesicles. Of these, the anterior ones are the largest, and the size decreases towards the posterior end of the body, so that one or both of the last two pairs may be practically indistinguishable in macroscopic view. The anterior sucker is about equal to the neck in width, and bears two or four pigmented patches which may be eyes. The posterior sucker is strongly contracted so as to be of lesser diameter than the body. The bursa is large, as are the male ducts. There are five pairs of testes. The ovaries are small. There is no copulatory area and no conducting tissue. Large clitellar glands are present. Posterior crop caeca are present and are almost completely fused together.

TABLE VII

Comparison of species of *Trachelobdella*

	Size in mm.	Annuli/ somite	Number of pulsatile vesicles	Annuli male/female pores	Eyes	Suckers	Host
T. lubrica (Grube, 1840)	50 long	(3) 6	12 pairs	3	None	Medium	Ectoparasitic on marine fish
T. mülleri Diesing, 1850	11 x 4-5	(3) 6	11-12 pairs	2	None	Medium	Parasitic on gills of Acanthopterygians
T. sinensis R. Blanchard, 1896	18 x 7	(3) 14	11 pairs	2	None	Small	? freshwater fishes
T. australis R. Blanchard, 1900	13 x 4	(3) 6	11 pairs	3	None	Medium	Parasitic on marine fish (usually teleosts)
T. turkestanica Scegelov, 1912	16·5 x 6		11 pairs	2	Present	Small	
T. carajbica Dequal, 1917	75 x 15				None		
T. okae Moore 1924	110 x 22	5	13 pairs		Present	Small	Marine fish
T. aralensis Dogiel and Bychowski, 1939	30 x 8	?(3) 6	11 pairs	?2	None	Contracted	*Barbus brachycephalus*
T. luderitzi Augener, 1936	4-7·5 x 1·5	(3) 4	11 or 13 pairs	2	None	Medium	
T. leptocephali sp. nov.	18 x 4	(3) 6	13 pairs	2	None	Small	Gills of *Leptocephalus conger*

External Features

The body is divided distinctly into two regions, an interior trachelosome and a posterior urosome. The trachelsome is short and sub-cylindrical, becoming wider at the clitellar region. There are 12 primary annuli in the pre-clitellar trachelosome, and three primary clitellar annuli. All the pre-clitellar annuli are subdivided by transverse furrows. These furrows also cross the clitellar annuli, but are not complete.

The anterior sucker is excentrically attached. In the centre of its inner face is a small raised area on which the mouth opens. On the dorsal surface of the anterior sucker there are usually two elongated pigmented patches, which in one specimen appear as four separate eye-like spots, arranged approximately at the corners of a square. No ocellar units were seen in section. Also visible on the outer surface of the sucker are five or six very fine concentric striations.

The urosome is considerably larger than the trachelosome. Its sides are sub-parallel throughout most of its length, but converge posteriorly. In distended specimens the posterior part of the urosome may be larger than the anterior. In section the urosome may be cylindrical or slightly depressed. Along the sides of the urosome are 13 pairs of pulsatile vesicles. Of these the anterior pairs are quite large and hemispherical, but the size diminishes towards the posterior end of the body, so that the last one or two pairs may not be apparent except in section. The pulsatile vesicles lie on the middle of the three primary annuli of the somite.

Each normal mid-body somite consists of three primary annuli, each of which is subdivided by a transverse furrow. The primary inter-annular furrows are deeper than the secondary ones. There are about 41 primary annuli visible on the urosome. Somites XIII-XXV inclusive are 3-annulate, and XXVI and XXVII are 1-annulate.

The anal region and posterior sucker are smaller than the mid-body region. Wrinkling is irregular here and so the exact number of annuli is difficult to determine. The sucker is tightly contracted so that its sides are parallel, and its edges wrinkled. If expanded it would be about equal to the body width in diameter.

Measurements of eight specimens are given below:—

TABLE VIII

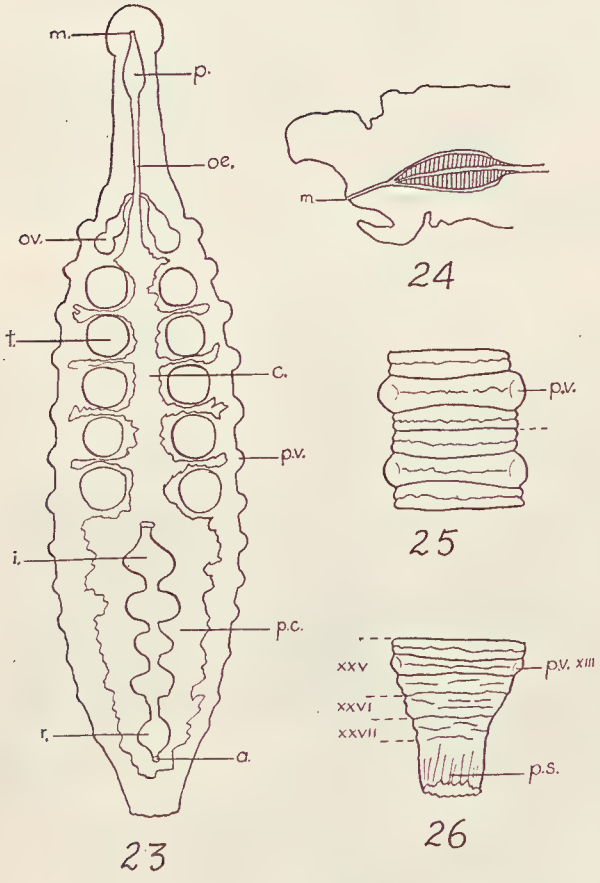
Measurements in mm. of eight specimens of *Trachelobdella leptocephali* sp. nov.

Specimen Number	Total Length	Maximum Width	Length of Neck
1	19	4	5
2	20	2	5·5
3	15	3·5	4·5
4	13·5	2	4
5	18	2	4·5
6	10	2·5	4
7	12	3·5	4
8	15	3	3·5
9	12	2	3

Internal Features

(*a*) *Bodywall and Musculature:* The epidermis is made up of closely packed columnar cells forming a layer about 20μ in thickness. This is covered by a very thin cuticle. The nuclei of the epidermal cells lie towards the base.

Beneath the epidermis is a well-developed connective tissue layer, about 30μ thick. Scattered throughout this layer are hypodermal gland cells, and stellate pigment cells. The pulsatile vesicles and capillaries of the coelomic system lie in the connective tissue layer.



Trachelobdella leptocephali sp. nov.

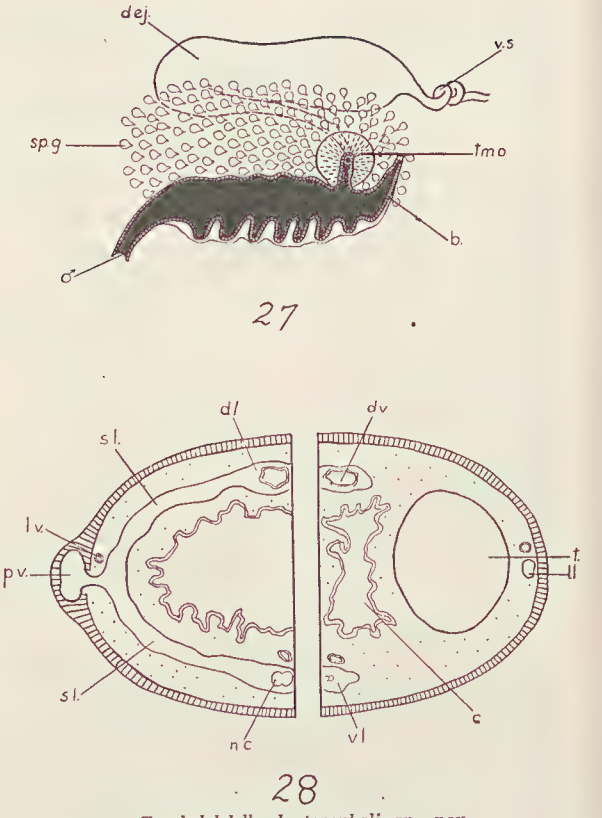
FIG. 23.—General anatomy in dorsal view.

FIG. 24.—Diagrammatic longitudinal section through the anterior sucker, showing the position of the mouth.

FIG. 25.—Two mid-body somites, showing annulation.

FIG. 26.—Posterior part of urosome.

a. anus; c. crop; i. intestine; m. mouth; oe. oesophagus; ov. ovary; p. proboscis; p.c. posterior crop caecum; p.s. posterior sucker; p.v. pulsatile vesicle; r. rectum; t. testis.



Trachelobdella leptocephali sp. nov.

FIG. 27.—Diagrammatic reconstruction of the right half of the male reproductive ducts and associated structures, viewed from the left side.

FIG. 28.—Diagrammatic transverse section through the testis region of the urosome showing the main coelomic elements. Left side segmental, right side intersegmental.

b. bursa; c. crop; d.ej. ejaculatory duct; d.l. dorsal lacuna; d.v. dorsal blood-vessel; l.l. lateral lacuna; l.v. lateral blood-vessel; n.c. nerve cord; p.v. pulsatile vesicle; s.l. segmental lacuna; sp.g. spermatophore gland; t. testis; t.m.o. terminal muscular organ; v.l. ventral lacuna; v.s. vesicula seminalis; ♂. male reproductive aperture.

The muscles of the body-wall form a layer about 100μ in thickness. Of this, about 80μ is made up of longitudinal muscle fibres, whilst the outer layers of diagonal and circular fibres make up the rest.

Both the anterior and posterior sucker are well supplied with small unicellular glands. Lying in the intestinal part of the urosome immediately inside the body-wall muscles and apparently associated with the posterior sucker, are a few very large unicelluler glands. These are largely confined to the dorsal part of the body, and have an average diameter of 250μ. The nucleus is lobed and has several nucleoli. The ducts, which have a diameter of about 12μ, leave the glands near their posterior margin, and appear to open on the inner surface of the posterior sucker. Their exact function is not known.

(*b*) *Coelom and Vascular System:* The main coelomic elements are dorsal, ventral, and lateral lacunae, with their segmental communications. The ventral lacuna lies beneath the gut, and contains the ventral nerve cord. At its interior end the ventral lacuna is greatly expanded, and envelops the proboscis and the anterior ganglonic mass. The dorsal lacuna lies above the gut, and contains the dorsal blood vessel. Anterior to the clitellar region the dorsal lacuna is not a separate structure but is united with the ventral lacuna and forms the median lacuna. In the urosome the dorsal and ventral lacunae are united segmentally by paired connectives. These are formed by dorsal and ventral branches given off from the dorsal and ventral lacunae respectively. These branches unite laterally with the lateral lacunae (figure 28). These are longitudinal coelomic vessels which lie near the lateral line among the longitudinal muscles. From the lateral lacuna, at the level of the segmental connective, a short transverse canal is given off, and passes out through the body-wall muscles to open into the pulsatile vesicle of that somite. Accessory segmental communications do not appear to be developed.

Coelomic capillaries are given off from the pulsatile vesicles, and ramify throughout the connective tissue layer.

One of the distinguishing features of leeches belonging to the genus *Trachelobdella* is the presence of non-pulsatile vesicles on the trachelosome. In this species the presence of these is doubtful, no definite vesicles being found.

The dorsal blood vessel lies within the dorsal lacuna, where it occupies most of the available space. The ventral vessel lies within the lacuna in the anterior part of the body, but leaves it about somite XIII. From here back to the beginning of the posterior ganglionic mass, the ventral blood vessel lies above the ventral lacuna. Paired lateral blood vessels are present, and lie dorso-laterally to the lateral lacunae.

(*c*) *Excretory System:* As in most piscicolids, excretion takes place by means of plectonephridia. The tubules are very fine (diameter 7μ) and ramify through the urosomal region.

(*d*) *Digestive System:* The mouth opening lies at the top of a small mound which is centrally placed in the oral sucker (figure 24). It leads into the proboscis sheath, which is short, extending only as far back as VII/VIII. The proboscis is short and muscular. On either side of the proboscis in somites VII to IX lie a number of large unicellular salivary glands. These have an average diameter of 100μ. The cytoplasm is granular, and the centrally placed nucleus is large, irregular in shape, and has more than one nucleolus.

The proboscis opens into the oesophagus, which extends back to XIII/XIV. Its walls are folded and are lined with a thick epithelium. There are no oesophageal pouches. The oesophagus is slightly expanded near its posterior end, where it is succeeded by the crop. This is a thin-walled structure, the main canal of which extends back to XX. It has six pairs of segmental expansions in XV to XX inclusive; sometimes a small anterior expansion occurs in XIV. From the posterior pair is given off a single, large posterior caecum, which extends, ventral to the intestine, back to the posterior end of the body just anterior to the anus. There is a possible fenestra in XXV, but this is not clearly defined. Throughout its entire length, the walls of the crop are greatly folded, thus providing room for considerable expansion.

The intestinal canal arises dorsally from the crop in XX. There is a slight anterior projection of the main intestinal canal ventral to this point. The intestinal epithelium is about three times as deep as that of the crop. There are four pairs of intestinal caeca, in somites XX to XXIII. The entire intestinal region is enclosed in a coelomic lacuna—the intestinal lacuna.

In XXIV the intestine opens into the rectum. This is a short expanded region which opens to the exterior at XXVI/XXVII.

(*e*) *Reproductive System:* Male organs: there are five pairs of testes lying intersegmentally in XIV/XV to XVIII/XIX. The testes are large rounded bodies which occupy the greater part of the body space. The vas efferens leaves the testis near the antero-ventral border, and passes up and out to open into the vas deferens, which is situated dorso-laterally. The vas deferens of each side passes forward to XIII, where it becomes expanded into a thin-walled, coiled seminal vesicle. The coils of this extend forward in the dorso-lateral position to about XII, where they pass into the glandular ejaculatory ducts. These are enormously enlarged bodies which extend forward to IX. Their walls are made up largely of polygonal gland cells and their ducts, which open into the narrow lumen. In IX the ejaculatory ducts become bent back and enter a loose mass of spermatophore glands. As they pass back through this mass the ducts decrease in diameter and converge. Near their ends they become surrounded by the exceedingly numerous ducts of the spermatophore glands, and together with these ducts, become united into a solid structure by an enveloping sheet of circular muscle fibres. The ejaculatory ducts unite into a common duct within this structure, and into this open the ducts of the spermatophore glands. This terminal glandulo-muscular organ in turn opens into the bursa on the postero-dorsal side of the latter structure. The bursa is a greatly enlarged sac which extends back from the male aperture in XI almost to XIII. Its walls, especially that of the ventral surface, are folded and muscular, and it is lined with a deep epithelium. A muscular organ of the bursa is also present in *Calliobdella*, but from the figures given by Johansson (1898, p. 591) it appears that the ejaculatory ducts and the muscular organ open separately into the bursa, whereas in *T. leptocephali* the ducts open into the bursa after uniting inside the muscular organ (figure 27). Attached to the sides of the bursa are retracter muscles which are inserted in the lateral body wall. It seems probable that the bursa is capable of protrusion as in some other piscicolid leeches, and serves as a copulatory organ.

Female Organs: the ovisacs are small, and lie in the ventro-lateral parts of XIII/XIV. The oviducts pass forward and unite in XII to form a

short muscular vagina which opens to the exterior at the female pore. A copulatory area and conducing tissue appear to be absent.

A number of mucous glands are present in the ventral part of the body immediately behind the clitellum, on the ventral surface of which they open. They probably have a lubricating function. Smaller ones surround the male aperture.

The clitellar glands are present throughout the urosome, where they form a layer immediately inside the body-wall musculature. The glands are small, having an average diameter of 50μ. Their ducts open at the clitellum. Clitellar glands are not present in the trachelosome. The clitellar glands have an average diameter of 50μ. The nucleus is large (about 25μ in diameter), central, lobed, and with several nucleoli. The ducts of the clitellar glands open on the clitellum. Also in the urosome, in somites XX to XXV, are a number of very large unicellular glands. These have an average diameter of 200μ although many are elongated parallel with the long axis of the body. The centrally placed nucleus has a diameter of about 80μ, and is markedly lobed. The function of these glands is not known, but they resemble the clitellar glands in the nature of the cytoplasm and nucleus. However, their ducts open on the posterior sucker.

(*f*) *Nervous System:* The nervous system agrees in general with that found in other piscicolids. The anterior ganglionic mass is short and compact, and ganglion VII is closely joined to it. Ganglia VIII to XI are fairly close together, then a long connective unites XI and XII. Ganglia XII and XIII are again close together; XIII to XXIV are fairly widely spaced; then follow three closely spaced ganglia and then the short broad posterior ganglionic mass.

Relation of the Leech to Its Host

Nine specimens of *Trachelobdella leptocephali* were taken from the gills of the common conger eel (*Leptocephalus conger* (Linnaeus)). The tightly constricted, almost tubular posterior sucker appears well adapted for attachment to the gill filaments.

"*ICHTHYOBDELLA*" *PLATYCEPHALI* sp. nov.

(Figures 29-34)

DIAGNOSTIC FEATURES

Members of this species are small leeches parasitic on the flathead, *Platycephalus bassensis* Cuv. and Val. The body of the leech is indistinctly divided into trachelosome and urosome. Two well-marked suckers, both attached excentrically, are present. There are no eyes. Lateral pulsatile vesicles are not visible externally; however, in section there are seen to be segmental expansions of the lateral lacunae. True vesicles are not formed, as these expansions do not occur outside the body-wall musculature. The complete somite is 14-annulate. In the male reproductive system there are five pairs of testes; the ejaculatory bulbs are long, and the atrial cornua short; there is a large bursa. An area of conducting tissue is present in the female system, and lies in somites XII/XIII. Oesophageal pouches are present in X/XI. The posterior caecum of the crop is completely unified. There are four pairs of intestinal caeca. Ten pairs of nephridia are present.

External Features

(*a*) *Size:* Only two specimens of this leech were available. The following measurements were made on the larger specimen:—

	Length	Width	Depth
Anterior sucker	2 mm.	2 mm.	
Neck	3 mm.	1·5 mm.	1 mm.
Clitellum	1·5 mm.	1 mm.	
Urosome	15·5 mm.	2·5 mm.	1·5 mm.
Posterior sucker	3·5 mm.	3·5 mm.	
Total length	23 mm.	2·5 mm.	(excluding suckers)

The smaller specimen, from which the internal anatomy was studied by means of serial transverse sections, had a maximum length of 10·5 mm.; the width in the neck region was 0·33 mm., and in the urosome, 0·71 mm.; the depth in these two regions was 0·35 mm. and 0·52 mm., respectively.

(*b*) Shape: The body is subcylindrical in the smaller, and only moderately depressed in the urosomal region of the larger leech. It is divided, but not distinctly, into an anterior trachelosome and a posterior urosome. The clitellum is slightly constricted.

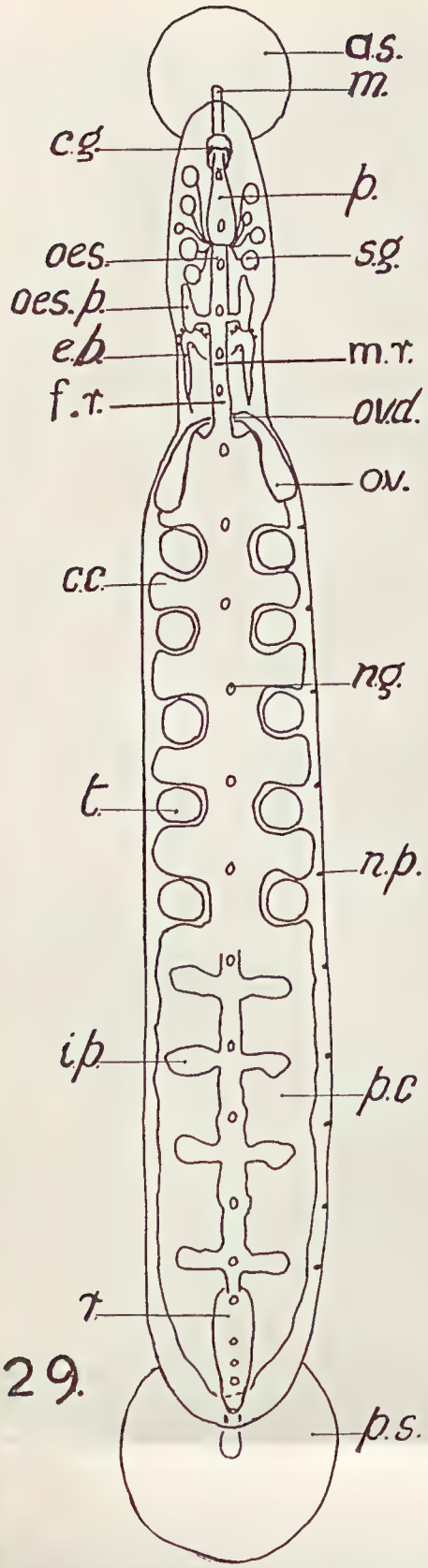
The oral sucker is disc-like, excentrically attached, and has an entire margin. The mouth opening is centrally situated on its inner face. The posterior sucker is almost twice the size of the anterior, disc-like when expanded, otherwise somewhat cup-shaped. The point of attachment of the posterior sucker is slightly excentric, the dorsal free edge being slightly longer than the ventral (2 : 1·5 mm.).

(*c*) *Colouration:* The outer surface of the anterior sucker has two conspicuous transverse dark bands. The more posterior of these is the darker and may conceal ocellar units although these were not found in section.

The dorsum and sides of the body are brown, and are marked by three pairs of longitudinal light bands dorsally, and with a fourth pair in the ventrolateral position. One pair is in the inner paramedian position, one, indistinct and discontinuous, in the outer paramedian position, and one is dorsolateral. The latter is expanded segmentally, each expansion extending through about four annuli.

The outer surface of the posterior sucker is irregularly mottled. The ventral surface of the body is pale, as are also the inner surfaces of the suckers.

(*d*) *Annulation:* To the unaided eye the skin appears to be smooth; under magnification, however, there is seen to be a large number of very small annuli. There appear to be about 30 annuli in the preclitellar region, comprising, together with the oral sucker, somites I to IX/X. The annulation of the clitellum is irregular and incomplete. There are three complete furrows, the anterior of which is oblique, and probably marks the posterior limit of X. This is followed by a dorsally incomplete groove, and then by a complete one. Slightly posterior to this and on the ventral side is the male reproductive aperture. Then follows a depression with a series of incomplete furrows, which may mark the posterior limit of XI. This is succeeded by a region crossed by one



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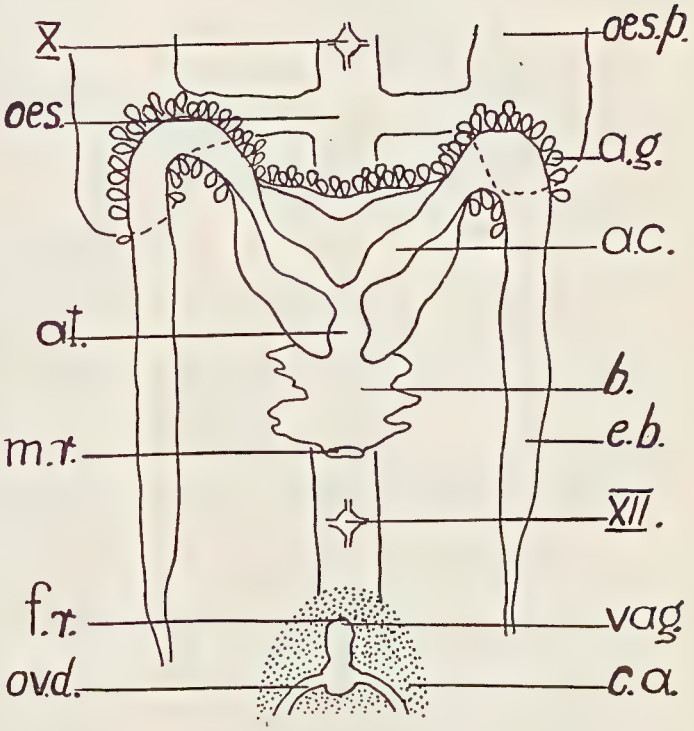

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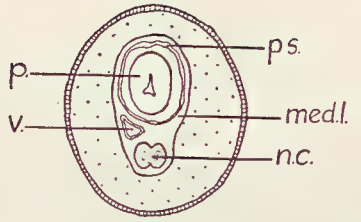
"Ichthyobdella" platycephali sp. nov.

FIG. 29.—General anatomy in dorsal view.

FIG. 30.—Diagram of male reproductive ducts in ventral view.

FIG. 31.—Diagram of the dark and light banding in the colour pattern. from the mid-dorsal position on the left of the figure, to the mid-ventral on the right.

a.c. atrial cornua; a.g. male accessory gland; a.s. anterior sucker; a.t. atrium; b. bursa; c.a. copulatory area; c.c. crop caecum; c.g. cerebral ganglion; e.b. ejaculatory bulb; f.r. female reproductive aperture; i.p. intestinal pouch; m. mouth; m.r. male reproductive aperture; n.g. nerve ganglion; n.p. nephridiopore; oes. oesophagus; oes.p. oesophageal pouch; ov. ovary; o.v.d. oviduct; p. proboscis; p.c. posterior caecum of crop; p.s. posterior sucker; s.g. salivary gland; r. rectum; t. testis; vag. vagina; X. XII, ganglia X and XII.



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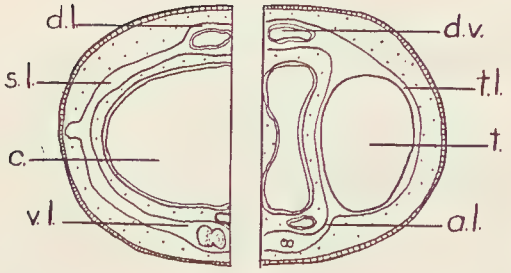

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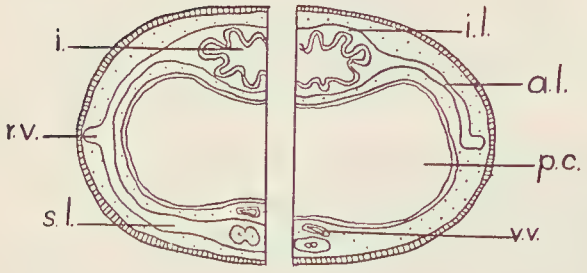

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"Ichthyobdella" platycephali sp. nov.

FIG. 32.—Diagrammatic transverse section of the trachelosome, showing the main elements of the coelom. The shaded area lies outside the body-wall musculature.

FIG. 33.—Diagrammatic transverse section through the testis region of the urosome; left side segmental, right side intersegmental.

FIG. 34.—Diagrammatic transverse section through the intestinal region of the urosome, left side segmental, right side intersegmental.

a.l. accessory segmental lacuna; c. crop; d.l. dorsal lacuna; d.v. dorsal blood-vessel; i. intestine; i.l. intestinal lacuna; med.l. median lacuna; n.c. nerve cord; p. proboscis; p.c. posterior caecum of crop; p.s. proboscis sheath; r.v. rudimentary vesicle; s.l. segmental lacuna; t. testis; t.l. testis lacuna; v. blood-vessel; v.l. ventral lacuna.

complete and by a ventrally incomplete furrow. A slight swelling, which may mark the position of the female pore is present immediately posterior to the complete furrow. The two furrows which mark the anterior and posterior limits of the clitellum are deeper than the other furrows.

The urosome consists of about 180 very short annuli. These, if the laterally placed light spots are segmental in arrangement, are arranged in groups of 14 to a complete somite.

Traces of annulation are also visible on the outer surface of the posterior sucker as fine concentric grooves.

Internal Anatomy

A series of transverse sections was made from the smaller specimen. As it was somewhat contorted the orientation of the sections was not always transverse, but was sufficiently so for the main anatomical features to be worked out. The sections were stained in Heidenhain's Iron Haematoxylin, according to the method given by Pantin (1946, pp. 39-40).

(*a*) *Body Wall and Musculature:* The outer layer of the body wall is a thin cuticle secreted by the one-layered epidermis. The epidermal cells are flattened, about 3·9μ in depth, and 9·1μ in width. The nucleus, which contains a nucleolus, lies near the base of the cell.

The connective tissue layer beneath the epidermis is very narrow; scattered throughout it are hypodermal gland cells which have a large secretion space.

The muscle layers are not strongly developed, the circular and longitudinal together forming a layer only 13μ in thickness. This fact, taken together with that of the poor development of dorsoventral muscles indicates that the leech was probably not an active swimmer.

In the connective tissue within the musculature are found the clitellar glands. These have a diameter of 26μ-39μ. They appear to have no special orientation. There is a very large secretion space occupying almost the entire cell and enclosed by a thin layer of densely granular cytoplasm. Towards one end of the cell this layer is thickened and contains the nucleus. The clitellar glands are present in both pre- and post-clitellar regions. Those in the pre-clitellum are found almost as far forward as the anterior ganglionic mass. The ducts are gathered into two longitudinal bundles, dorso-lateral in position.

In the post-clitellar region the glands are found in greatest abundance between the crop expansions; where the testes occupy the greater part of the lateral space the glands are clustered dorsally and ventrally. The ducts of the post-clitellar glands are gathered into six bundles. These are dorso-lateral (2) and ventro-lateral (2) and dorsal (2).

The ducts of the clitellar glands open on the clitellum.

The tissue of the posterior sucker contains well-developed sucker glands, which lie nearer the outer surface. They are found throughout the sucker except for the point of attachment and a marginal band.

(*b*) *Respiratory System:* No specialized respiratory structures, such as branchiae or pulsatile vesicles are developed. However, the lateral sinuses have segmental expansions which may be the rudiments of lateral canals connecting up with vesicles (figs. 33-34).

(*c*) *Digestive System:* The mouth is a small opening centrally situated in the anterior sucker. It leads to the proboscis, which lies within the proboscis-sheath and extends back to VIII/IX, where it enters the long thin-walled oesophagus. The salivary glands lie on either side of the proboscis and anterior part of the oesophagus. The salivary glands are large, having an average diameter of 0·1 mm. The secretion space is large and is enclosed within vesicular cytoplasm. The nucleus is a large triangular body with numerous nucleoli. The ducts, 6μ in diameter, of the salivary glands enter the base of the proboscis and then continue their course inside the proboscis to open at its anterior end. Inside the proboscis they are represented by six large longitudinal ducts.

Between X/XI the oesaphagus gives off paired oesophageal pouches. These have a narrow opening into the oesophagus but expand forward ventrally and laterally. Although the crop was well-filled with food, these pouches were quite empty. It has been suggested that, such pouches, in other Piscicolid leeches, are glandular in function, or that they contain symbiotic bacteria (Autrum, 1932-34, p. (8) 301).

The oesophagus enters the crop slightly behind XIII. This is a large thin-walled structure, the main canal of which extends back to XIX where it enters the intestine. The crop has a series of six segmental expansions. From the last of these is given off a single median caecum which extends back to XXVII. There are four very small fenestrae in XIX, XX, XXI, and XXII. The intestine, which is given off from the crop in XIX and lies dorsal to the caecum, has four pairs of lateral pouches in XIX/XX, XX/XXI, XXI/XXII and XXIII. In XXIV the intestine enters an expanded rectal chamber, which terminates at the anus.

(*d*) *Reproductive System: Male Organs:* There are five pairs of testes situated in XIV/XV, XV/XVI, XVI/XVII, XVII/XVIII and XVIII/XIX, between the crop expansions. On either side a vas deferens passes forward, and about the level of XIII, expands into an elongated seminal vesicle or ejaculatory bulb. The two bulbs continue forward almost to X, where they turn ventroposteriorly and enter the muscular ejaculatory cornua. These are short and unite a short distance behind and ventral to XI. The short muscular atrium opens into a well-developed bursa with folded walls. This opens at the male aperture between XI and XII.

The anterior parts of the ejaculatory bulbs are covered with a mass of unicellular spermatophore or prostate glands. In the midline, immediately above the union of the ejaculatory cornua is a reservoir by way of which many of the central glands open into the atrium.

Female organs: There is a single pair of ovaries lying laterally in XIII-XIV. They gradually pass anteriorly into narrow oviducts which converge towards the midline ventrally and unite to form a short vagina. This is directed antero-ventrally and opens at the female pore in XII-XIII.

Associated with the female part of the reproductive system is an area of conducting tissue. This extends longitudinally from XII to XIII/XIV; transversely it occupies about half the ventral surface. In this region, the epidermis becomes thickened (39μ) and has a folded appearance. It is widely separated from the underlying musculature by the development within the connective tissue, of a mass, 52μ in thickness, of glandular tissue. Such tissue in other leeches has been referred to as " leitendes Gewebe " or " tissu vecteur ". (Brumpt, 1901.)

(*e*) *Nervous System:* The central nervous system lies within the ventral lacuna. Its ganglia are extremely large and well-developed. The general structure is the same as for other Piscicolid leeches. The position of the ganglia is shown in figure 29.

(*f*) *Coelom and Vascular System:* The coelomic system consists of the following parts: median, dorsal, ventral, and segmental lacunae.

Median lacuna: this occurs in the trachelosome, where it contains the proboscis and related structures. In the urosome it splits and gives rise to the dorsal and ventral lacunae. In addition to the proboscis the median lacuna contains the ventral nerve cord, the anterior ganglionic mass, and associated blood vessels.

Dorsal lacuna: this consists of two parts—a testicular portion and an intestinal portion. The former lies above the gut and contains the dorsal blood vessel. From it arise two sets of segmental lacunae, the main and the accessory communications, lying in the middle and posterior parts of the somite respectively. In the intestinal region the dorsal lacuna is expanded and surrounds the intestine.

Ventral lacuna: lies beneath the gut and contains the ventral nerve cord. The ventral blood vessel does not lie within the ventral lacuna, but slightly above it. The ventral parts of the segmental lacuna arise from the ventral lacuna. The ventral lacuna is quite small.

Segmental lacunae: these are of two kinds—main and accessory. The main communication of the testis region forms a complete ring around the gut, and is made up of dorsal and ventral branches arising from the dorsal and ventral lacunae respectively. These branches unite, near the lateral line and in this region the lacuna becomes expanded. The structure so formed resembles the " rudimentary vesicle " figured by Moore (1952, fig. 7*a*) in his description of *Johanssonia abditovesicula*. The accessory communication of the testis region consists also of a complete ring, which is widely expanded and contains the testes. The main communication in the intestinal region resembles that of the testis region in that it is a complete ring. The accessory communication however, lacks the ventral part. It consists of a curved branch running from the dorsal lacuna to the lateral line.

In this region the swollen part of the main segmental lacuna gives off a very fine canal which passes back along the lateral line and unites with the lateral end of the accessory communication. This canal does not appear to be present in the testis region.

There are no lateral lacunae and no pulsating vesicles such as occur in *Johanssonia* Selensky, 1914.

(*g*) *Excretory System:* There are 10 pairs of nephridia lying laterally in somites XIV-XXIII. The main body of the nephridium lies anterior to the nephridiopore, which opens immediately behind the level of the ganglion of its somite. The nephridium commences laterally, then pursues a somewhat convoluted course towards the dorsal part of the body, where it changes direction and passes down to the ventral part. Here it again turns and passes dorsally and posteriorly till it reaches the mid-lateral line. Then the nephridium becomes constricted before expanding into a bulb opening on the surface. No trace of internal funnels was found.

Affinities

In 1914 Selensky (1914*a*) described a leech parasitic on a pantopod, and gave it the provisional name of "*Ichthyobdella*" *pantopodum*. Later in the same year he (Selensky, 1914 *b*) described a leech from *Anarrhichas lupus* (Linn.) and erected a new genus *Johanssonia* to accommodate this species, which he named *J. kolaensis*. He then assigned his earlier "*Ichthyobdella*" *pantopodum* to his new genus. In 1952, Moore described a leech from *Tetraodon hispidus* Linn. which he called *Johanssonia abditovesicula*, noting however that it differed quite markedly from the description of *Johanssonia kolaensis* given by Selensky (1914 *b*), from which the following is taken:—Small leeches with well-formed suckers of less diameter than the body; both somewhat excentric. Body cylindrical and not distinctly divided into trachelosome and urosome. Skin smooth. Lateral lines marked by the presence of 11 pairs of lateral vesicles; of these the last pair may be reduced or absent. No eyes. Normal mid-body somite made up of 14 (16) annuli. Posterior crop caecum with five fenestrae. Ciliated organs present in the nephridial system. Six pairs of testes. Male system has no "Johansson's organ" in the long bursa; however, the common part of the ejaculatory ducts is provided with a glandular muscular groove which projects into the bursa. Conducting tissue and a copulatory area are present.

Table VIII gives a comparison of the three species assigned to the genus *Johanssonia*, and also includes the Tasmanian species which appears to be related quite closely to *J. abditovesicula*. As Moore recognized, his species does not lie with certainty in the genus *Johanssonia*, and it seems possible that when more material becomes available the systematic position of both *J. abditovesicula* and "*Ichthyobdella*" *platycephali* may be determined more precisely.

Distribution

Two leeches were collected from flathead at Catamaran, south Tasmania.

TABLE VIII

Comparison of species of *Johanssonia* and "*Ichthyobdella*" *platycephali* sp. nov.

	Johanssonia kolaensis Selensky, 1914	*Johanssonia pantopodum* (Selensky, 1914)	*Johanssonia abditovesicula* Moore, 1952	"*Ichthyobdella*" *platycephali* sp. nov.
Maximum length	23 mm. +	20 mm.	15 mm.	23 mm.
Annuli/somite	14 (16)	14	14	14
Eyes	None	None	None	None
Skin	Smooth, with small lateral vesicles	Smooth, with small lateral vesicles	Smooth	Smooth
Shape	Body cylindrical, imperfectly divided into 2 regions	Body cylindrical, imperfectly divided into 2 regions	Body divided into 2 regions, but not markedly	Body cylindrical narrower, anteriorly and imperfectly divided into 2 regions
Pulsatile vesicles	11 pairs	11 pairs	No true vesicles	No true vesicles
Oesophageal pouches	Not mentioned	Not mentioned	Not mentioned	Present
Posterior crop caecum	United, with 5 fenestrae	United, with 5 fenestrae	United, ? with 2 fenestrae	United, ? with 2 fenestrae
Nephridia	With ciliated funnels	With ciliated funnels	Not mentioned	10 pairs, without funnels
Female system	With copulatory area and conducting tissue	With copulatory area and conducting tissue	Not mentioned	With copulatory area and conducting tissue
Male system	With glandulo-muscular organ of bursa	With glandulo-muscular organ of bursa	Ejaculatory cornua surrounded by male accessory glands	Ejaculatory cornua surrounded by male accessory glands
Testes	6 pairs	6 pairs	5 pairs	5 pairs
Ventral blood vessel	Outside ventral lacuna	Outside ventral lacuna	Outside ventral lacuna	Outside ventral lacuna
Host	*Anarrhichas lupus* (Linn.)	*Nymphon strömii* Kröyer	*Tetraodon hispidus* Linn.	*Platycephalus bassensis* C. & V.

Genus **BRANCHELLION** Savigny, 1820

GENERIC FEATURES

Posterior body-region two or three times as broad as the anterior, flattened, and with paired lateral leaf-like appendages on almost all rings. Members of the genus are entirely marine.

Type: *Branchellion torpedinis* Savigny, 1820.

A table comparing the chief features of the different species assigned to this genus is given hereunder (table IX). Richardson regards the presence of tubercles as one of the characters in which *B. australis* differs from *B. parkeri*, and Moore (1952, p. 43) refers to ". . . tubercles, which are conspicuously developed in *B. australis*." However, in the original description of *B. australis*, Leigh-Sharpe (1916, p. 46) made no mention of tubercles, but said, "There are on the dorsal surface . . . very conspicuous patches where the pigment is absent, giving to the unaided eye the appearance of whitish spots." These spots are apparently regarded by both Richardson and Moore as tubercles, or at least indicating the presence of them. It was hoped to be able to determine the nature of the spots by reference to the type specimen, but this is no longer available, and appears to have been lost.

A species of *Branchellion* which occasionally is found on certain Tasmanian Elasmobranchs, appears to be identical with the New Zealand form, *B. parkeri*. The following description is based on an examination of both young and adult specimens.

The specimens were preserved in 5 per cent formalin.

BRANCHELLION PARKERI Richardson, 1949

(Figures 35-44)

? *B. raiae* Parker, 1892.

B. parkeri Richardson, 1949; 1953.

DIAGNOSTIC FEATURES

Branchellion parkeri is a branchiate leech, usually 2-4 cm. in length, but occasionally attaining a length of 7 cm. Externally it has 31 pairs of branchiae borne laterally on the abdominal annuli. At the base of the branchiae on every third annulus is a pulsatile vesicle; in all, these comprise 10 pairs. There are four post-branchiate annuli, the last two of which are post-anal. Eyes and ocelli are lacking. The body is smooth and without tubercles. The dorsal surface of each annulus is marked by the presence of four, six or eight white spots arranged in a transverse row.

The crop has six pairs of lateral caeca, from the last of which is given off ventrally a posteriorly directed median diverticulum. The intestine has four pairs of lateral caeca. The female reproductive organs are a pair of ovaries which pass anteriorly into paired oviducts. These unite to form a short vagina, opening at the female aperture in the clitellum. Behind the ovaries lie five pairs of testes in somites XIII-XVII. The male reproductive aperture is situated in front of the female pore; there is a short blunt, ornamented penis.

External Characters

(*a*) *Size:* Adult Tasmanian specimens of *B. parkeri* range in total length from 17 mm.-75·5 mm. and in the total width (including the branchiae) from 3 mm.-12·5 mm.

TABLE IX

Comparison of recognised species of *Branchellion Savigny*

Feature	*B. parkeri*	*B. australis*	*B. borealis*	*B. ravenelii*	*B. torpedinis*	*B. orbinensis*	*B. lobata*
No. of gills	31 pairs	31 pairs	31 pairs	31 pairs	33 pairs	33 pairs	31 pairs
Tubercles/spots	No tubercles. 4 white spots on each annulus (Richardson, 1953)	Tubercules on all annuli of the neck, and 4, 6, or 8 on the abdominal annuli (Richardson, 1949) Leigh-Sharpe (1916) mentions only white spots in the above positions	The 1st annulus of the 3-annulate segments of the neck has 4 warts dorsally, as also the 1st annulus of the clitellum.	No tubercles	1st annulus of each segment of abdomen has 6 white spots dorsally and 4 ventrally	No warts on the prelitellum. 4 longitudinal rows of white spots on the neck on each annulus and 6 on the dorsal and 4 on the ventral surface of the abdomen on the 1st annulus of each somite	No tubercles
Pulsatile vesicles	10 pairs	11 pairs	11 pairs	11 pairs	11 pairs	11 pairs	11 pairs
Post-branchiate annuli	4	6	6	4	....	....	5
Post-anal annuli	2	3	3	1	....	....	2
Testes	5 pairs	6 pairs	....	5 pairs	....	....	5 (1 with 6 pairs
Eyes	None	None	None	1 pair, asymmetrical mid-longitudinally	6 eyes on the 5th segment of the anterior sucker	....	1 pair of irregular ocellar units
Shape of anterior sucker	Sub-circular hooded	Hoodlike	Circular	Cup-shaped	....	Circular	Expanded, disc-like
Pigmentation of anterior sucker	2 transverse black pigment patches, one on either side of the midline	8 or 9 large black pigment spots	Sucker dark. 2 darkest areas with 4-5 light spots	....	....	Black pigment dispersed	....

N.B.—*B. intybifolium*, *B. lineare*, *B. punctatum* and *B. imbricatum* are inadequately described.

TABLE X

Measurements in mm. of 27 specimens of *B. parkeri* from Tasmanian waters.

Total Length	Width of Body including Gills	Total Length	Width of Body including Gills
5	0·5	17	3
6	0·5	17	3
7	1	24	4
7	2	26	6
8	0·5	31	9
9	1	32	6
9	1	32	6
10	1	32	8
10	1·5	32	8
11	1·5	35	9
12	1·5	43	7
13	2	54	10·5
15	2	75·5	12·5
15	3		

A series of measurements made on specimens of this leech from Tasmanian waters is given in Table X.

(*b*) *Shape* (figure 35): The body of the adult leech is divided into two clearly defined regions, the trachelosome and the urosome. In small immature forms the trachelosome is not so sharply constricted off from the urosome, there being a gradual development from the cylindrical form of the young to the shape of the adult, which has a marked shouldered appearance, and in which, although the trachelosome is still sub-cylindrical, the urosome is dorso-ventrally flattened. Two distinct disc-shaped suckers are present.

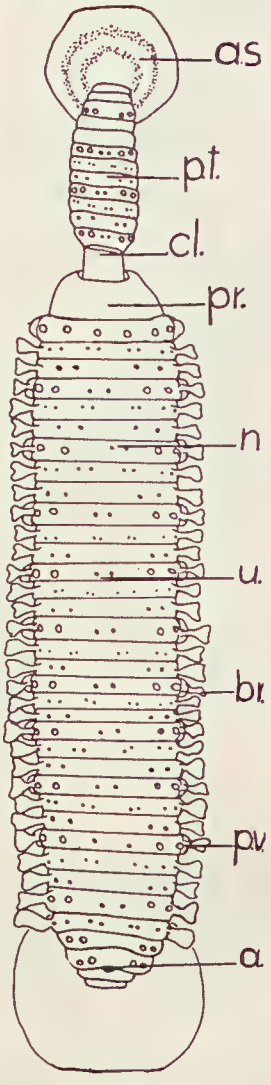
(*c*) *Colouration:* The ventral surface of the entire animal is very pale and shows no definite pattern. The inner surfaces of the two suckers are similarly lacking in dark pigmentation. A few scattered brown pigment spots are present in both regions.

The dorsum of the anterior sucker is pigmented light brown and bears two conspicuous concentric bands of darker pigmentation; these are more clearly defined in young forms with lighter body pigmentation. In larger specimens they tend to merge with one another and form a darkly pigmented region over the entire proximal part of the sucker. The dorsum of the neck, abdomen (with the exception of the last two annuli) and the posterior sucker are coloured dark-brown by numerous melanophores. The neck is, in general, paler than the rest of the dorsum; similarly, there are fewer melanophores on the distal edges of the gills and on the pulsatile vesicles. The margin of the posterior sucker is similarly lacking in pigmentation.

The dorsum of both body and posterior sucker has a pattern of creamy-yellow spots, the arrangement of which is described below.

In general, young specimens up to about 12-15 mm. long are lighter in colour, and show very little differentiation between dorsal and ventral surfaces. As a result, the pigmentless patches on the dorsal surface are more difficult to distinguish; however, they appear to have the same arrangement, described below, as in the larger and darker specimens. In no case are the light spots raised up as tubercles.

Richardson has described both patterned and colourless phases among the New Zealand specimens of *B. parkeri*.



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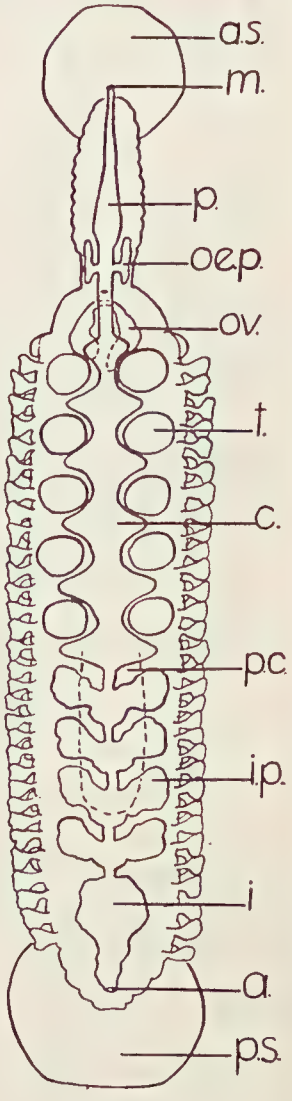


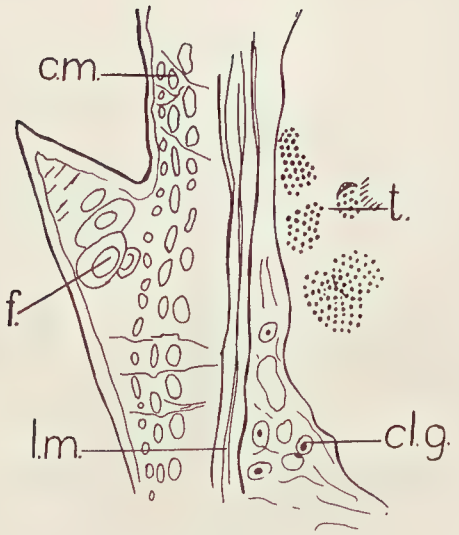
36.

Branchellion parkeri Richardson, 1949.

FIG. 35.—External features, dorsal view.

FIG. 36.—General anatomy, dorsal view.

a. anus; a.s. anterior sucker; br. external branchial appendage; c. crop; cl. clitellum; i. intestine; i.p. intestinal pouch; m. mouth; n. neural or sensory annulus characterized externally by the presence of four large and two medium-sized light spots, and by a pair of lateral pulsatile vesicles; oe.p. oesophageal pouch; ov. ovary; p. proboscis; p.c. post-caecum of crop; pr. prepuce; p.s. posterior sucker; p.t. preclitellar trachelosome; p.v. pulsatile vesicle; t. testis.



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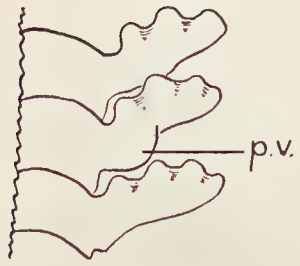

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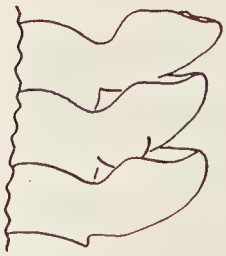


39.

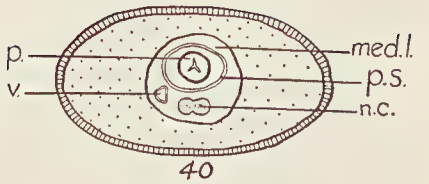
Branchellion parkeri Richardson, 1949.

FIG. 37.—Longitudinal section of part of the ventral body-wall of *B. parkeri* showing the position of the fat cells.

FIG. 38.—Ventral view of three branchiae of a New Zealand specimen of *B. parkeri*.

FIG. 39.—Ventral view of three branchiae of a Tasmanian specimen of *B. parkeri*.

c.m. circular muscles; cl.g. clitellar gland; f. fat cell; l.m. longitudinal muscle; p.v. pulsatie vesicle; t. testis.



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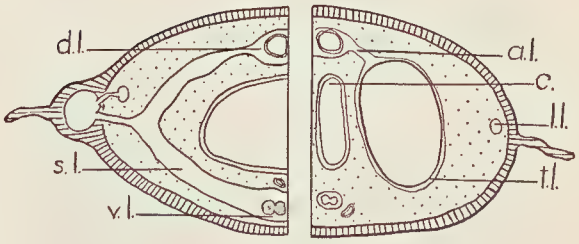

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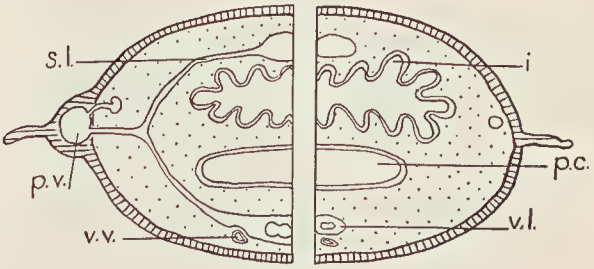

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Branchellion parkeri Richardson, 1949.

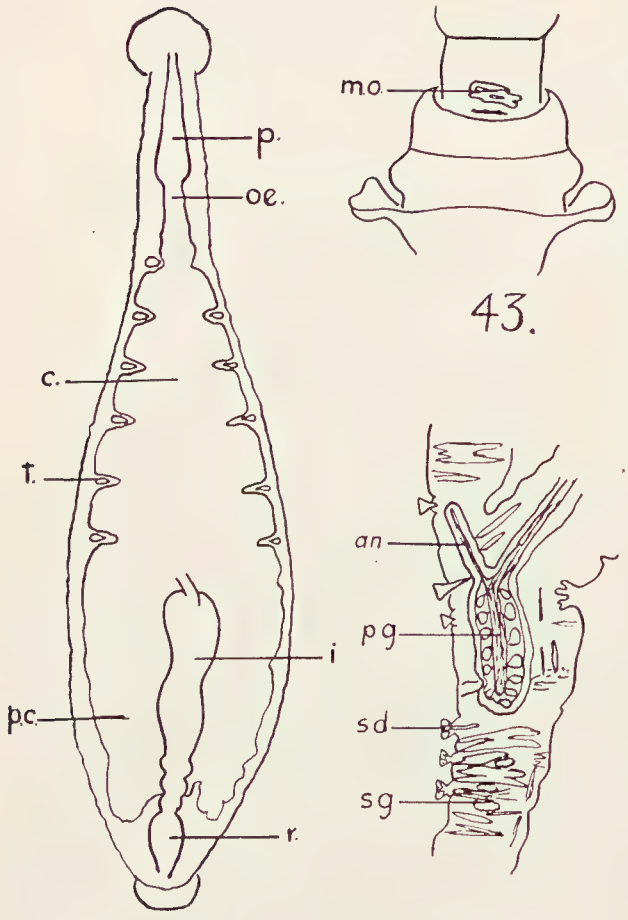
Diagrammatic transverse sections through the body showing the main coelomic elements. The shaded area lies outside the body-wall musculature.

FIG. 40.—Trachelosome.

FIG. 41.—Testis region of the urosome; left side segmental, right side intersegmental.

FIG. 42.—Intestinal region of the urosome; left side segmental, right side. intersegmental.

a.l. accessory segmental lacuna; c. crop; d.l. dorsal lacuna; i. intestine; l.l. lateral lacuna; med.l. median lacuna; n.c. nerve cord; p. proboscis; p.c. posterior caecum of crop; p.s. proboscis sheath; p.v. pulsatile vesicle; s.l. segmental lacuna; t.l. testis lacuna; v. blood-vessel; v.l. ventral lacuna; v.v. ventral blood-vessel.



45. 44. 43.

Branchellion parkeri Richardson, 1949 and *Pontobdella tasmanica* (Hickman, 1942).

FIG. 43.—Ventral view of clitellar region of *B. parkeri* showing the partly protruded male organ.

FIG. 44.—Diagrammatic longitudinal section of part of the posterior sucker of *B. parkeri*.

FIG. 45.—Dorsal view of digestive system of *P. tasmanica*.

a.n. anterior nerve branch in sucker; c. crop; i. intestine; m.o. male organ; oe. oesophagus; p. proboscis; p.c. posterior caecum of crop; p.g. posterior ganglionic mass; r. rectum; s.d. sucking disc; s.g. sucker gland; t. testis.

With the possible exception of some of the small specimens, all the Tasmanian examples belong to the patterned dark phase. However, the lack of colour in the small specimens may be due to the action of the preservative on the initially weaker pigmentation.

There are minor differences in the arrangement of the spots in the Tasmanian and New Zealand specimens. Three types of spots may be distinguished by differences in size; they may be classed as large, medium and small. In all the Tasmanian examples these spots have the following arrangement (see Table XI).

In the abdominal region the spots occur on the anterior half of the annulus. The arrangement of the spots is shown in fig. 35. As can be seen, it is very similar to that given by Leigh-Sharpe for *B. australis*. However, *B. parkeri* differs from the latter species in having only 10 pairs of pulsatile vesicles, and only five pairs of testes.

(*d*) *Annulation* (fig. 35): In the specimens before me the neck region exhibits only 12 of the 13 annuli mentioned by Richardson, only two of the three very small anterior annuli being present. These two are fused ventrally. The 3rd annulus is larger than normal and incompletely divided by a dorsal furrow. In contrast to the condition found in the abdomen, the spots on this annulus are situated posterior to the furrow. Immediately behind the neck, the body is constricted into a clitellar region, the greater part of which is hidden by the prepuce—an anteriorly reflected fold of the body-wall. Behind the prepuce the body appears to consist of 37 annuli.

TABLE XI

Patterning of *B. parkeri* from Tasmania.

Position		Spots		
		Large	Medium	Small
Pre-clitellar Trachelosome Annulus:	1	0	0	0
	2	0	0	0
	3	4	0	0
	4	0	0	0
	5	0	0	0
	6	4	2	0
	7	0	0	0
	8	0	4	0
	9	4	2	0
	10	0	0	8
	11	0	4	0
	12	4	2	0
Clitellum somites XI, XII		Unpigmented		
Urosome somite:	annulus:			
XIII	a_1	Unpigmented		
	a_2	6	0	0
	a_3	0	0	8
XIV-XXIII				
	a_1	0	4	0
	a_2	4	2	0
	a_3	0	0	8
XXIV		4	0	0
XXV		4	0	0
XXVI		0	0	0
XXVII		0	0	0

The 1st two apparent annuli of the abdomen are non-branchiate, the 1st is larger than most of the succeeding ones, and the 2nd, a sensory annulus, bears laterally a pair of pulsatile vesicles. The following 3-33 inclusive, bear laterally-projecting, foliaceous outgrowths (branchiae). These are expanded distally and have simple margins. The

furrows which incompletely divide the dorsum of each abdominal annulus are less conspicuous in the Tasmanian specimens than in those from New Zealand.

There are 10 pairs of pulsatile vesicles, one pair being borne on every 3rd (i.e., sensory) annulus. Behind the last pair of pulsatile vesicles are four branchiate annuli. The pulsatile vesicles are situated laterally, at the base of the branchiae. Behind the last branchiate annulus are four non-branchiate rings. The anus is situated in the mid-dorsal line between the 2nd and 3rd of these.

The ventral surface of the abdomen is marked by forwardly-projecting extensions of the annuli arising at the interannular furrows Laterally these flanges are in direct communication with the branchiae.

The prepuce forms a collar completely encircling the clitellum and ventrally may cover the reproductive apertures (but see below). These are close together, the male lying slightly anterior to the female. In the clitellar region no annulation is evident.

The anterior sucker is subcircular, becoming somewhat hoodlike in the larger specimens, but never as much so as in *B. australis* (Leigh-Sharpe, 1916, pp. 44-45, figs. 1 and 2); the posterior sucker is larger and flatter, and quite circular. Well-developed radial and circular muscles are visible in the tissue of the suckers. In the anterior, the circular, and in the posterior, the radial muscles predominate. The inner surface of the posterior sucker is covered with small attachment discs.

Internal Anatomy

The internal anatomy was studied by means of longitudinal sections stained with Heidenhain's Iron Haematoxylin. Some sections were counter-stained with eosin, according to the method given by Pantin (1946, pp. 39-40).

(*a*) *Body-wall and Musculature:* The epidermis consists of a single layer of cells having their nuclei towards their bases, and is covered externally by a thin cuticle which, on the dorsal surface, is thicker than on the ventral surface.

The epidermal cells have an average height of 21μ, and an average width of 8μ. The nuclei contain a darkly staining nucleolus. Among the epithelial cells are goblet-shaped gland cells which secrete mucus. These are slightly larger than the epithelial cells and are granular in appearance.

Beneath the epidermis is a connective tissue layer. This has an average thickness of 26μ. Beneath the connective tissue lie the muscle layers. These are arranged in an outer circular and an inner longitudinal series. There are three layers of circular muscles, the innermost of which, especially on the ventral surface of the body, is the most strongly developed. The circular muscle layer lies in connective tissue and forms a layer about 0·026 mm. in thickness. There appear to be two layers of longitudinal muscles, which however, for the most part, are so closely united as to be practically indistinguishable from one another. The average thickness of the longitudinal muscle layer is 0·052 mm. A series of dorso-ventral muscles pass between the gut pouches in the posterior part of the body. In transverse sections the muscles have a lobed appearance.

In this genus, as in *Austrobdella,* clitellar or cocoon glands lie between the subdermal musculature and the alimentary canal. In the Tasmanian specimens, the region occupied by the clitellar or cocoon glands extends from the posterior limit of the clitellum to the anal region. The glands are in the form of unicellular structures, usually rounded but occasionally somewhat angular. Their average dimensions are: length = 0·0531 mm. x width =0·0388 mm. x height = 0·0319 mm. The main body of the gland consists of dense but finely granular cytoplasm. The nucleus, a somewhat flattened, darkly staining body, is situated within this. The secretion space, at one end of the gland cell, also is enclosed in the cytoplasm. The space contains scattered granules. From the secretion space, the duct of the gland passes forward The ducts are gathered into eight bundles. Laterally two such bundles, one dorsal and the other ventral, lie inside the musculature. About the level of somite XIV, they unite to form a median lateral bundle. Anteriorly this bends towards the midline where it unites with the rest of the clitellar gland ducts. These are in paired dorsal and ventral bundles. The openings of the ducts are in the clitellar region within the prepuce.

In the Tasmanian specimens of *B. parkeri* fat cells are associated with the ventral, forwardly projecting flanges of the body-wall (fig. 37). Within each flange, a number of cells form a band transverse to the long axis of the body. They are entirely confined to the ventral surface of the body. This arrangement is similar to that in *B. torpedinis.*

The fat cells are rounded, elongated dorso-ventrally. The long axis has a dimension of about 39μ; the intermediate axis is parallel with the long axis of the body and has an average dimension of 34μ; and the shortest axis is parallel with the transverse axis of the body, and has an average length of 30μ. The cytoplasmic cell body is densely granular. It stains moderately with haematoxylin and very darkly with eosin. The nucleus is centrally placed, and is somewhat irregular in shape. Several nucleoli are present. They appear black when stained with haematoxylin and also when counterstained with eosin.

In addition to the general musculature of the body, strongly-developed muscle bands are found in the posterior sucker (fig. 44). The sucker is lined throughout with epidermis covered with cuticle. The actual attachment is by means of small disc-like structures arranged quincunxially. These are covered with epidermis and set in a socket of connective tissue. A muscle strand extends vertically into the disc. In between the muscle bands of the sucker are large numbers of rounded unicellular glands, with long ducts which open to the exterior through pores on the ventral surface of the small suckers. The glands are aggregated into large glandular masses, and are called "sucker-glands". Scriban and Autrum (1932-34) describe the appearance of these in *B.*

torpedinis Savigny on pages (8) 126, and (8) 146. These glands lie near the inner surface and are present throughout the entire tissue of the sucker (fig. 44). The ducts of these glandular aggregates open in the centre of the sucking discs, which have a slight central depression.

(*b*) *Respiratory System:* Respiration takes place by means of branchiae and pulsatile vesicles (fig. 35). The branchiae are 31 pairs in number. The vesicles are situated at the base of the branchiae on the sensory annuli.

The pulsatile vesicles are 10 pairs in number. The vesicle, which is covered by epidermis, is largely composed of connective tissue, except for a central space. Medially this becomes constricted, and leads by a very narrow canal to the lateral longitudinal vessel within the body (figs. 41-42, see also (*c*) *coelom*, below).

Richardson (1949 *a*, p. 10) gives a full description of the mode of respiration in the New Zealand specimens.

(*c*) *Coelom and Vascular System:* The coelom, which is greatly reduced, consists of four main longitudinal elements—a dorsal, a ventral, and paired lateral sinuses. The dorsal and ventral sinuses are connected segmentally by connecting sinuses. Laterally from the connecting sinuses a transverse vessel is given off to the lateral sinuses. The dorsal, ventral and connecting sinuses are thin-walled, but the lateral sinuses have muscular walls and are contractile. As mentioned above, paired branches, leading to the pulsatile vesicles, are given off from the lateral sinuses in the middle annulus of somites XIII-XXII. Two vessels enter each pulsatile vesicle, one from the contractile lateral sinus, and one from the segmental lacuna. The former vessel opens into the vesicle in a position dorsal to that of the segmental lacuna.

The dorsal sinus contains the dorsal blood-vessel. In the intestinal region the dorsal blood-vessel gives rise to the intestinal sinus. This is essentially a close network of fine blood-vessels which ramify over the surface of the intestine. A single all-enveloping sinus, such as is found in other leeches is not present. A ventral blood vessel lies in the connective tissue beneath the ventral sinus. The central nervous system and the ovaries lie within the ventral sinus.

(*d*) *Excretory System:* This consists of 11 pairs of plectonephridia, segmentally arranged in somites XIII to XXIV. These are best seen in partly macerated and compressed preparations. The nephridia appear as a series of segmental tubules arising from paired longitudinal vessels in the intermediate ventral position. Only one pair of nephridiopores appears to be present—those of somite XXIV. There are no funnels and no capsules.

This very primitive nephridial system is similar to that described by Bourne (1884, pp. 481, 486) for *Branchellion torpedinis*. In that species also there is apparently only one pair of nephridiopores, opening ventrally on somite XXIV.

(*e*) *Digestive System* (figure 36): In the specimens before me the mouth opens at the base of the anterior sucker and leads into the proboscis sheath. The sheath extends back as far as the 8th ganglion in the ventral nerve cord (i.e., the 2nd free ganglion behind the cerebral mass). The proboscis is straight and strongly muscular. The ducts of the salivary glands enter at the base of the proboscis. The glands are arranged in a cluster of about 20 on either side of the proboscis.

Behind the proboscis is the narrow, thin-walled oesophagus. This, from lying centrally in the cylindrical neck region, becomes curved dorsally in an arc above the nerve cord and reproductive apertures. In X, the ducts of a pair of large thin-walled oesophageal pouches enter the oesophagus. The oesophagus extends back as far as ganglion XII, where it is followed by the crop, which is provided with six pairs of lateral pouches, placed respectively in somites XIII, XIV, XV, XVI, XVII and XVIII. The 1st and 6th pairs of pouches differ from the intervening ones. The 1st are of much smaller lateral extent, and the 6th gives off posteriorly, a large-sized diverticulum lying in the mid-ventral line. This extends back as far as the 3rd pair of intestinal diverticula which lie above it. It is perforated by five fenestrae.

The crop diverticula have simple walls.

Above ganglion XVIII the crop passes into the intestine, lying above the median crop diverticulum. The intestine consists of a median tube which gives off four pairs of lateral pouches, in somites XIX, XX, XXI and XXII. Unlike those of the crop caeca, the walls of these are plentifully supplied with small accessory pouches and are highly vacular. Behind the pouched region, the intestine is an unbranched tube with similar wall structure, lying above ganglia XXIV-XXVI. It passes posteriorly into a short rectal chamber which swings upward, to open at the anal aperture in the mid-dorsal line. The inner wall of the entire intestinal region differs from that of the crop and rectum in being thickened.

(*f*) *Reproductive System: B. parkeri* resembles *B. ravenelii* in having five pairs of testes. These lie in XIII/XIV, XIV/XV, XV/XVI, XVI/XVII and XVII/XVIII. From the testes on either side, a vas deferens passes forward. The two vasa deferentia are situated dorso-laterally within the longitudinal muscles. They have very thick walls. The vessels are 18μ in diameter and have a lumen with a diameter of 9μ. Paired vasa efferentia leave the testes on their median side and pass up and out to unite with the vasa deferentia. The seminal vesicle recorded by Richardson (1949 *a*, p. 9) as being present in the New Zealand specimens appears to be absent in some of my specimens. This appears to be due to a difference in degree of dilation, as in some it is quite large, while in others it is merely a narrow tube.

Anteriorly, the vas deferens becomes a much convoluted tube, lying lateral and dorsal to the gut. It leads to the muscular ejaculatory duct, extending as far forward as IX, where it turns towards the ventral surface and becomes greatly expanded to form the ejaculatory horns, in which the sperma-

tophores are produced. The horns unite and open by a short blunt penis into the atrium lying in IX/X. In a specimen taken on *Dasyatis* sp. from Pittwater (November, 1950), the penis is partly protruded (fig. 43) and is seen to have a frilled margin. Dorso-ventral retractor muscles are attached to the terminal part of the male system.

The ovaries are paired and lie close to the midline in XIII, above the ganglion of that somite. Anteriorly each gives off an oviduct which runs into a short common muscular vagina in XII, which opens by the female pore situated midventrally in this somite. The walls of the oviducts are surrounded by conductive tissue.

(*g*) *Nervous System:* There is a ventral nerve cord with ganglia segmentally arranged along its length, except that the ganglia of the 1st six and last seven somites are aggregated into masses. Both cord and ganglia are double.

The ganglia of somite I lie dorsal to the proboscis in the 3rd and 4th free annuli, and constitute the cerebral ganglia. These are connected by periproboscidial connectives with the main ganglionic mass lying beneath the proboscis sheath. This mass contains the fused ganglia of somites II to VI. Close behind lie the ganglia of somites VII and VIII. The ganglia of somites IX, X, XI and XII lie on an arc above the reproductive apertures and below the alimentary canal. Ganglion XIII is ventral in position. Then follow ganglia XIV to XXIII, each lying in the middle annulus of its somite. Ganglia XXIV-XXVII lie close together, owing to the reduction in annulation of these four posterior somites. The posterior grouping is characteristic of *Branchellion*. Extending from segment XXVII into the posterior sucker is found the terminal ganglionic mass. This contains seven paired ganglia belonging to the seven somites (XXVIII-XXXIV) which constitute the posterior sucker. At the antero-ventral end of this ganglionic mass is given off a thick nerve branch which supplies the lower surface of the sucker (see fig. 44).

Habits

Richardson (1949 *a*, p. 9 and 1953, p. 292) is the only author who has published observations on the living animal. He describes *B. parkeri* as being for the most part an inactive leech, capable, however, of swift but erratic movement when roughly treated.

Unfortunately no live material from Tasmanian waters is available.

Richardson remarks that the inability of *B. parkeri* to swim is probably one of the most important factors in limiting its host range to bottom-dwelling forms.

In New Zealand waters *B. parkeri* occurs on *Raia nasuta, Mustelus antarcticus, Callorhynchus milii* and certain skates. In Tasmania, specimens are found on *Raia lemprieri, Pristiophorus* sp. and *Dasyatis* sp.

With the exception of *Pristiophorus* and *Mustelus*, all these hosts spend a large part of their time on the bottom, mainly feeding on shell fish. It would, therefore, not be difficult for the *Branchellion* to attach itself to any one of these fish.

The occurrence of *Branchellion* on *Pristiophorus* presents a different problem. *Pristiophorus* is largely a fish feeder (Whitley, 1940, p. 154) and spends considerable part of its time actively swimming after its prey. However, since it is a ventrally flattened animal, it is fairly safe to assume that it spends some time on the bottom and may even feed on bottom-dwelling fish.

Similarly, the occurrence of *Mustelus* as a host for *Branchellion*, at first sight appears strange as it belongs to a family of sharks however, it has adopted a bottom-dwelling life and a diet which includes molluscs. To this end its teeth have become crushing plates (Young, 1950, p. 177).

Distribution

Up to the present this species has been recorded from New Zealand. The localities are as follows:—

Richardson, 1949 *a*: *B. rajae* is common on dogfish in Cook Strait.
Richardson, 1949 *b*: *B. rajae* on *Raia nasuta* (no locality given). *B. parkeri* on *Mustelus antarcticus* from the vicinity of Wellington.
Richardson, 1953 : *B. parkeri* on a skate, off Dunedin; also some trawled off Cape Campbell.

In Tasmanian waters, *B. parkeri* has been obtained from the following new hosts and new localities:—

on *Raia lemprieri* Richardson, 1845, North West Bay; and Port Sorell.
on *Pristiophorus* sp., Port Sorell.
on *Dasyatis* sp., Pittwater.

Comparison with New Zealand Specimen

A comparison of the Tasmanian form with a specimen of *B. parkeri* from *Raia nasuta*, Cook Strait, New Zealand, revealed several interesting features. In addition to the differences in patterning, the form of the gills (figs. 38 and 39) differed in the specimens from the two localities. In *B. parkeri* from New Zealand the gill margins showed more folding than in those from Tasmania; in the latter they are only slightly wavy, whereas in the former they appear frilled.

Genus **PONTOBDELLA** Leach, 1815

GENERIC FEATURES

Marine leeches, ectoparasitic on skates and rays. Body long and cylindrical, without pulsating vesicles or branchiae, covered by papillae which usually project as conspicuous spiny or warty protuberances but may be partly or entirely retracted. Anterior sucker discoid and excentrically attached, posterior sucker centrally attached and campanulate. Without eyes. Complete somite formed of 3, 4 or 5 rings, the number being constant within the species.

Type: *P. verrucata* Leach, 1815.

PONTOBDELLA TASMANICA (Hickman, 1942)

(Figure 45)

DIAGNOSTIC FEATURES

Pontobdella tasmanica belongs to the 3-annulate species of *Pontobdella*. It closely resembles *P. loricata* Harding in having 12 tubercles on each a_1 and a_3, and 8 on a_2, but has only 5 clitellar annuli. The mid-dorsal tubercles on a_1 and a_3 in *P. tasmanica* are smaller than those on the rest of the annulus.

A leech, attached to a piece of *Ulva* and referable to this species was collected by J. L. Hickman, 13.10.1952, on Kingston Beach. From it the following observations were made. The body is cylindrical, 12 mm. long and has a maximum breadth of 1·5 mm. in the mid-body region and of 0·5 mm. in the neck region. Two suckers are present and are clearly marked off from the rest of the body. The anterior sucker is excentrically attached, and the posterior one centrally. There are 57 annuli in the body between the two suckers, and they are arranged in 3-annulate somites (with the exception of I-VI anterior sucker, XI, XII, XXV, XXVI, XXVI and XXVII-XXIV posterior sucker). The alimentary canal, as seen in a compressed whole mount, shows a general resemblance to that of *P. benhami* Richardson, 1950.

In the specimen of *P. tasmanica* under examination the proboscis extends back to IX. From here a thin-walled oesophagus extends back to XII, where it expands into the wide simple crop. Intersegmentally this is constricted into seven compartments, the last of which ends at XIX. From here, a median ventral caecum extends back to about XXV, although its posterior limit is difficult to determine, and probably varies with the state of engorgement. Dorsally at the posterior end of XIX, the simple intestine, which is of smaller diameter than the crop, is given off. This is constricted off in XXII/XXIII from a somewhat beaded region with three compartments, the posterior of which is constricted off from the bulbous rectum in XIII/XXIV.

The male reproductive system contains six pairs of testes situated intersegmentally between the crop expansions. Paired ejaculatory cornua unite to form the atrium which opens to the exterior by the male reproductive aperture, situated in XI a_2/a_3.

A 2nd and much larger specimen of *P. tasmanica* was collected by Mr. A. M. Olsen. It had the following measurements:—

Total length: about 80 mm.
Maximum width: 10 mm.
Maximum thickness: 10 mm.
Width of neck: about 4 mm.
Diameter of anterior sucker: 2·5 mm.
Diameter of posterior sucker: 5·5 mm.

Distribution

This species has previously been recorded from Sandy Bay, Hobart (Hickman, 1942) as previously mentioned; the small specimen described above was collected at Kingston, Tasmania. The large specimen was collected from a skate from Brig Rocks, King Island, on 2.4.1951.

Family GLOSSIPHONIIDAE

Sub-family GLOSSIPHONIINAE

Genus **GLOSSIPHONIA** Johnson, 1816

GENERIC FEATURES

Small to moderately large glossiphoniids with two or three pairs of eyes. The complete somite is 3-annulate. The crop has six pairs of lateral caeca, the last of which is elongated and posteriorly directed. Seminal vesicles and ejaculatory ducts form a long open loop. The male and female reproductive apertures are either united or separated by one or two annuli. Salivary glands are diffuse.

Type: *Hirudo complanata* Linnaeus, 1758.

Four species of *Glossiphonia* have previously been recorded from Australia; they are:—

G. australiensis Goddard, 1908. Oberon, N.S.W. Goddard, 1908.
G. heteroclita (Linnaeus, 1758). Gosford N.S.W. Goddard, 1909.
G. inflexa Goddard, 1908. Waverley, Sydney. Goddard, 1908.
G. intermedia Goddard, 1909. Fairfield, N.S.W. Goddard, 1909.

A comparison of these species is given in table XIII. Goddard (1908, p. 321) recorded a *Glossiphonia* from Tasmania, but from his text, it is not clear to which of the above species he is referring. Since *G. australiensis* is the species most widely distributed, it is probably this.

The specimens of *Glossiphonia* at my disposal were collected at two localities: Lake Dulverton, and a small creek running into the Curryajong Rivulet at Antill Ponds. The leeches from the two different localities represent two species. That from the latter appears to be new, and the specific name *G. tasmaniensis* is proposed for it.

TABLE XIII

Comparison of species of *Glossiphonia* previously described from Australia

	Glossiphonia australiensis Goddard	*G. heteroclita* (Linn.)	*G. intermedia* Goddard	*G. inflexa* Goddard
Average size	10 mm. x 5 mm. 15 mm. long extended	8·8 x 2·6 mm.	33 mm. extended 14 x 4·6 contracted	14 x 4·5 mm.
Colour of body	Body flesh coloured	Usually amber-yellow with paired median black dots	Anterior half blue-grey posterior yellow crop caeca green	Pale sage green
Transparency of body	Body opaque	Body clear and gelatinous	Body translucent-transparent	Body semi-translucent
Number of eyes	3 pairs on annuli 2, 3	3 pairs on 5 (6) 7, 8, or 4, 5, 6 (Goddard)	2 pairs on 5, 6	None
Number of annuli	70	68-72 (70)	70	?
Number of annuli on anterior sucker	Anterior sucker constituted by 7 annuli		Posterior lip formed by annulus 8	
Nature of body surface	Body surface rough and devoid of papillae in macroscopic view; in section it is seen to be covered by a large number of papillae	Smooth and without sense papillae	Sense papillae small white tubercles on every 3rd annulus behind 21, 4 on each, the 2 paramedians being the larger	Sense papillae in mid-body on every 3rd annulus
Position of anus	1 post-anal ring	No post-anal rings (?1)	2 post-anal rings	Anus dorsal on last annulus
Reproductive apertures	Male and female apertures separated by 1 very narrow annulus	Male and female apertures united in furrow between XI i/XI ii	Male/female: apertures separated by 1 annulus (28)	Reproductive apertures united on the 28th annulus
Crop caeca	6 pairs, the last pair extending from 44-60, and carrying 11 small lateral branches	6 pairs of caeca, simple, except for the 6th, which has 5 secondary diverticula	Crop with 6 pairs of caeca of which the 6th is larger and has 3-4 side branches	?
Intestine	Intestine with 4 pairs of auriform caeca	4 pairs	4 pairs of elongated auriform sacs	?
Number of testes	6 pairs of testes	6 pairs	6 pairs	?

GLOSSIPHONIA TASMANIENSIS sp. nov.

(Figures 46-49)

DIAGNOSTIC FEATURES

G. tasmaniensis is small, lanceolate in outline, colourless and transparent. The alimentary canal, when containing food, is visible through the body wall. Three pairs of eyes are present, one pair on each of annuli 6, 7, and 8. The total number of annuli is 70. Between the last two of these is the anus. Each member of the 6th pair of crop caeca has 4-5 small side branches. In the male reproductive system the number of testes varies from 4-5 pairs, one or both of the first two pairs normally present in species of *Glossiphonia* being absent. The ejaculatory ducts are long and muscular; they unite, and the duct so formed opens into the common genital space. One pair of elongated ovaries is present, extending from XIII to XVII. The oviducts unite to form a short vagina which forms a collar round the nerve cord. The vagina opens into the common genital space. This opens to the exterior at 28/29.

External Features

(*a*) *Size:* The leech is small, being 7-10 mm. long and 3-4 mm. wide.

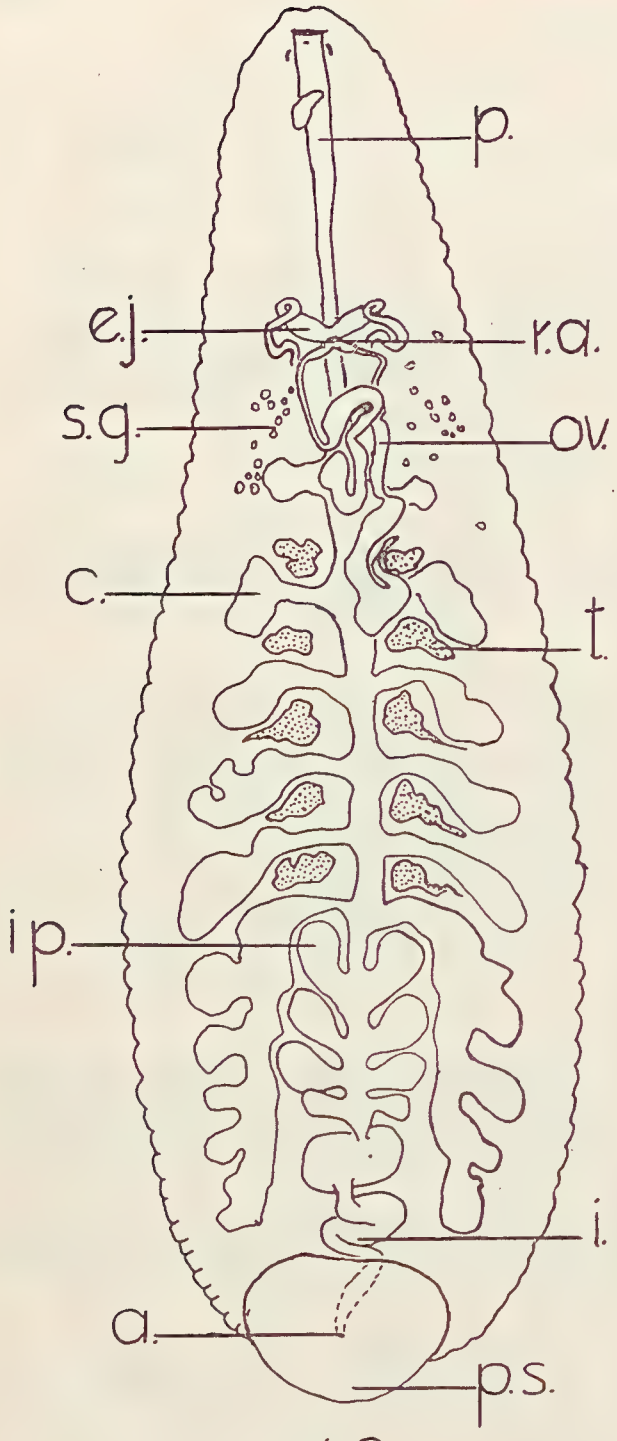
(*b*) *Shape:* In outline it is lanceolate, pointed anteriorly, rounded posteriorly. The body is depressed, somewhat rounded dorsally and flat or concave ventrally. The oral sucker is not divided off from the body, but is a slightly concave region surrounding the mouth on the anterior ventral surface. This anterior attachment area extends over annuli 1-5, the 6th being the first complete annulus ventrally.

A distinct disc-like posterior sucker, slightly less than half the maximum body width in diameter, is present. It is little wider than long; the sucker is terminal, centrally attached and ventral in aspect.

There are three pairs of eyes on annuli 6, 7 and 8. The first pair is small, close to the midline, and but lightly pigmented. The 2nd and 3rd pairs are wider apart and darker; often there appears to be but a single eye on either side.

The total number of annuli is 70. The reproductive apertures are united at 28/29, and the anus opens between 69/70.

(*c*) *Pigmentation:* In the living state the leech is a small transparent mass of almost colourless to greyish-white jelly, which could pass unnoticed

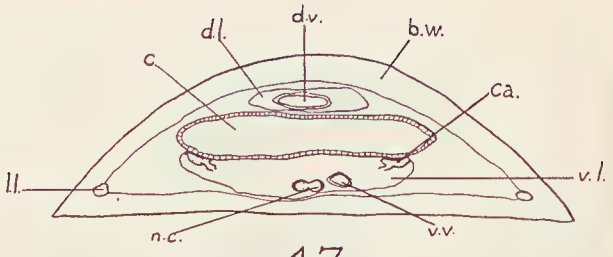


46.

Glossiphonia tasmaniensis sp. nov.

FIG. 46.—Whole animal, showing the main systems.

a. anus; c. crop; ej. ejaculatory horn; i. intestine; i.p. intestinal pouch; ov. ovary; p. proboscis; p.s. posterior sucker; r.a. reproductive aperture; s.g. salivary gland; t. testis.



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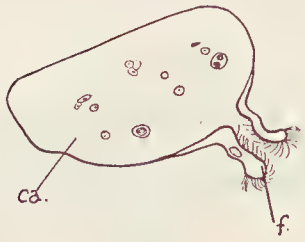

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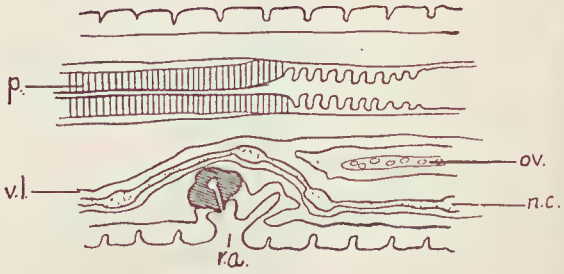


49.

Glossiphonia tasmaniensis sp. nov.

FIG. 47.—Diagrammatic transverse in the mid-body region, showing the position of the main organs.

FIG. 48.—Nephridial capsule and ciliated funnel.

FIG. 49.—Diagrammatic longitudinal section in the mid-line, showing the reproductive aperture.

b.w. body-wall; c. crop; ca. nephridial capsule; d.l. dorsal lacuna; d.v. dorsal blood-vessel f. ciliated funnel of the nephridium; l.l. lateral lacuna; n.c. nerve cord; o.v. ovary; p. proboscis; r.a. reproductive aperture; v.l. ventral lacuna; v.v. ventral blood-essel.

against the dark surface of the stones under which it is found, if it were not for the crop diverticula. These, because of the food which they contain, appear almost black.

When killed, and fixed in Bouin's Fixative, the leeches lose their transparency.

Internal Anatomy

This was studied by means of compressed whole mounts stained in alum carmine, and also by means of longitudinal and transverse sections stained in Heidenhain's Iron Haematoxylin; the transverse sections were counter-stained in eosin.

(*a*) *Bodywall and Musculature:* The body is covered by a thin cuticle secreted by the epidermis. The epidermal cells are very small, columnar in shape, and have their nuclei towards their base. The thickness of the cuticle and the epidermis together is 7·8μ. Essentially epidermal in nature, but projecting into the sub-epidermal region are numerous goblet-shaped gland cells. These have a granular secretion which stains deeply with haematoxylin but is unaffected by eosin. Each gland opens by a narrow duct on the middle of the annulus. The average size of these gland cells is 30μ x 10μ. The glands are much more numerous on the dorsal than on the ventral surface. The connective tissue layer is thin.

The longitudinal and circular muscles are well-developed, especially the latter. They together form a layer about 80μ in thickness.

In addition, dorso-ventral muscles are present, mainly in the posterior body region, where they are found between the paired diverticula of the alimentary canal.

The musculature of the posterior sucker is composed mainly of oblique fibres which enter the sucker from the body. At the junction between the body and the sucker a network of fibres is developed.

(*b*) *Coelom and Vascular System:* The coelom is represented by dorsal, ventral and lateral lacunae. Throughout the greater part of the body the dorsal lacuna contains the dorsal blood-vessel. In the intestinal region this blood-vessel becomes greatly enlarged and envelopes the intestine and its caeca as the intestinal sinus.

The ventral lacuna is much larger than the dorsal and contains the ventral nerve cord, the ventral blood-vessel and the ovaries. Anteriorly the lacuna becomes expanded to enclose the proboscis and related nervous structures. The two main longitudinal sinuses are connected by segmental commissures. In the testis region these are enlarged as the testicular lacunae and contain the testes.

The lateral longitudinal lacunae lie in the lateral angle of the body and are connected with the segmental lacunae by a short transverse branch.

(*c*) *Excretory System:* The excretory organs are nephridia. These occur in somites VIII-XXIV. The nephridia of the 1st and of the last two somites lack the ciliated opening into the ventral lacuna. In the clitellar somites no nephridiopores are present.

The nephridium opens to the exterior from a vesicle at the nephridiopore. This is situated on the ventral surface midway between the mid-ventral and lateral lines. The diameter of the vesicle is 31μ.

Internally, the nephridium opens by a ciliated neck into the ventral lacuna. The openings are situated dorso-laterally. The neck is about 39μ in length and leads into a large bladder (having a diameter of up to 90μ), which is frequently filled with intra-capsular leucocytes. The neck is lined with cilia which are directed towards the bladder.

(*d*) *Digestive System:* The mouth lies about the middle of the oral sucker and leads to the proboscis sheath; this contains the hollow muscular proboscis. The lumen of the proboscis is 3-cornered in section. The proboscis is long, extending back to XII, and it can be protruded for a distance equal to half the length of the body. It is succeeded by the short oesophagus, which is lined internally by a thick columnar epithelium. The oesophagus is succeeded in XIII by the crop, the two being separated by a constriction. Six pairs of caeca are given off from the sides of the crop. They lie in XIV, XIV/XV, XV/XVI, XVI/XVII, XVII/XVIII, and XIX-XXVI. The anterior pair is the smallest, and the succeeding pairs become larger. The 6th pair arises in XIX, and becomes elongated and directed posteriorly. Each of the members of this pair bears four to five accessory side-branches.

The central crop canal ends in XIX, where it is separated by a constriction from the following intestinal region. The anterior part of this bears four pairs of auriform caeca; these are found in XX, XXI, XXII and XXIII. The caeca are directed slightly forwards and those of the anterior pair are the largest.

The posterior part of the intestine consists of two expanded chambers, followed by the rectum. The anterior of these chambers in XXIII/XXIV, is very large, and ventral in position. It is closely constricted off on its postero-dorsal aspect from the 2nd chamber. This is followed by the rectum which opens mid-dorsally between 69/70.

Associated with the oesophagus is a paired mass of unicellular salivary glands, which extends through several segments. The ducts of these glands open into the base of the proboscis. The glands have a large secretion space and the nucleus lies in the cytoplasm at one side of this. The average diameter of the glands is 80μ.

(*e*) *Reproductive System:* In most other species the male and female apertures are separate, but in *G. tasmaniensis* they show the comparatively unusual feature of being united.

Male Organs: There are only four or five pairs of testes. The four pairs usually present lie between crop caeca 2/3, 3/4, 4/5, and 5/6; i.e., in somites XV, XVI, XVII and XVIII. If a 5th pair is present it is between caeca 1/2; i.e., in somite XIV. Sometimes only one member of the anterior pair is present; this was on one occasion found anterior to the 1st pair of crop caeca.

Anteriorly the paired longitudinal vasa deferentia become enlarged and muscular to form the ejaculatory ducts. The duct on each side is somewhat convoluted, and extends forward as far as X, where it turns ventro-posteriorly. The left and right ducts converge and unite in XI. The atrium opens into the common genital space.

Female System: The female organs are a pair of elongated and somewhat convoluted ovaries, extending back as far as XVII/XVIII. Anteriorly in XIII they pass into paired oviducts, which unite above and below the nerve cord to form a short muscular vagina, in the form of a collar encircling the ventral nerve cord. The vagina opens into the common genital space. The collar-like structure around the nerve cord is also known from *G. complanata* (L.) (Lameere, 1931, p. 196).

(*f*) *Nervous System and Segmentation*: The central nervous system consists of a double median ventral ganglionated chain. There are 21 free ganglia in addition to the anterior and posterior concentrations of six and seven ganglia respectively.

The macroscopically visible sense organs are three pairs of eyes in annuli 5/6, 7 and 8. The 1st pair lies close to the midline and is poorly developed. The pigmentation of this pair is paler than that of the two larger succeeding pairs. The 2nd pair of eyes is wider apart, darkly pigmented, and has an antero-lateral aspect. The eyes of the 3rd pair lie very close to those of the 2nd pair; they are also darkly pigmented and have a postero-lateral aspect.

Habits

These glossiphoniids, collected on the under surface of stones in a small creek at Antill Ponds, are very sensitive to light and spend most of their time under any cover that is available. This habit may be correlated with their lack of pigmentation.

Specimens of *G. tasmaniensis* were kept in fresh-water in Kilner jars. By changing the water regularly and providing a few small fresh-water snails as food from time to time, no difficulty was experienced in keeping the leeches alive for several weeks. The leeches devoured the snail, leaving an empty shell.

Affinities

G. tasmaniensis appears to be closely related to the *G. heteroclita-G. weberi* group, and in fact may be a variety of *heteroclita* (table XIV). However, in the literature concerning the latter species I have been able to find only one reference to individuals possessing fewer than six pairs of testes, that being in Johansson's paper (1918, p. 376) where he records five pairs. Other workers do not appear to confirm this. This may be due to the number that is most commonly present being given. In no case was the variation in the number of testes shown by the Tasmanian specimens due to immaturity.

TABLE XIV

Comparison of species of *Glossiphonia* which show similar features.

Character	*Glossiphonia heteroclita* (Linn.)	*G. weberi* Blanchard	*G. novae-caledoniae* Johansson	*G. tasmaniensis* sp. nov.
Size	9·5 mm. x 5 mm.	6-12 mm. x 3-55 mm.	5·5 mm. x 3 mm.	7-10 mm. x 3-4 mm.
Colour	Body amber-yellow at times grey-white never brown or brightly coloured. Sometimes with a median row of black spots	Ground-grey to orange, usually with 5 longitudinal rows of dark spots	Grey-white with median segmentally arranged spots	Grey-white
Eyes, 1 pair on each of annuli	5 (6), 7, 8 (varies)	6, 7, 8 (varies)	5, 7, 8	5, 7, 8
Total number annuli	70	70	70	70
Lower lip of oral sucker	5 and 6	5 and 6	4	5 and 6
Nature of body surface	Almost smooth	5 rows of papillae	No papillae median dorsal ridge present	Surface very finely granular. No segmental papillae
Post-anal rings	0	1	0	1
Position of reproductive aperture	United between 28/29	United: 27/28 or 28/29	Male: 26/27 Female: 27/28	United: 28/29
Number of testes	6 pairs	6 pairs	5 pairs	4 or 5 pairs

Only one other species of *Glossiphonia* has been described as having fewer than six pairs of testes, and that is *G. novae-Caledoniae* Johansson (1918, p. 376) where the number given is five pairs. This species, however, differs quite markedly from the Tasmanian specimens in that it has a low median dorsal ridge and the reproductive apertures are separated by one annulus (table XIV).

Distribution

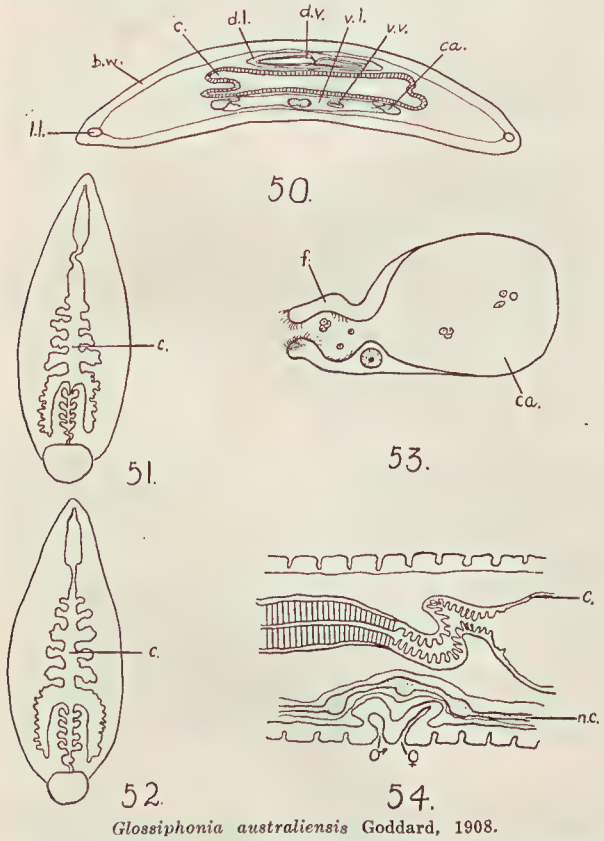
Specimens of *G. tasmaniensis* were collected at Antill Ponds. They were taken from the under surface of stones in the creek running into the Curryjong Rivulet in this locality. The collection was made on 10th March, 1954. At this season, a large percentage of the leeches were carrying young.

GLOSSIPHONIA AUSTRALIENSIS Goddard 1908

(Figures 50-54)

DIAGNOSTIC FEATURES (after Autrum, 1936, p. 14).

The body is flesh-coloured and opaque; it resembles *G. heteroclita* in general appearance. There is a pair of eyes present on each of annuli 2, 3 and 4, those of the 1st pair are smaller than the succeeding ones and are closer together; the eyes of the 2nd pair are very close to those of the 3rd. The posterior sucker is small. Altogether there are 70 annuli, one of which is post-anal. Papillae are not macroscopically visible. The mouth-opening lies slightly in front of the middle of the oral sucker. There are six pairs of crop caeca, the last of which extend from ring 44-60, and bear numerous (11) side-branches. There are four pairs of auriform intestinal caeca. Six pairs of testes are present; coiled seminal vesicles (in the ventral lacuna) are lacking. Ovisacs have a lateral diverticulum on either side of the union with the oviduct. Male and female apertures are separated by one annulus, which, however, is so short that outwardly the reproductive apertures appear to be united; male: 28/29; female: 29/30. Leeches 10 mm. long x 5 mm. wide.



Glossiphonia australiensis Goddard, 1908.

FIG. 50.—Diagrammatic transverse section in the mid-body region, showing the position of the main organs.

FIG. 51.—Immature individual with only five pairs of crop caeca.

FIG. 52.—Mature individual with the normal six pairs of crop caeca.

FIG. 53.—Nephridial capsule and ciliated funnel.

FIG. 54.—Diagrammatic longitudinal section in the mid-line, showing the reproductive apertures.

b.w. body-wall and muscles; c. crop; ca. nephridial capsule; d.l. dorsal lacuna; d.v. dorsal bloo-vessel; f. ciliated funnel of the nephridium; l.l. lateral lacuna; n.c. nerve cord; ♂. male reproductive aperture; ♀. female reproductive aperture; v.l. ventral lacuna; v.v. ventral blood-vessel.

The Tasmanian specimens show some slight variation from the above. The reproductive apertures are clearly distinct, and are separated by a well-defined annulus. The male aperture may be surrounded by swollen lips.

External Features

(*a*) *Size:* This leech is capable of considerable extension and contraction and so the average size is difficult to determine. The larger specimens are, when at rest, about 15 to 20 mm. in length, and 4 to 5 mm. in width. They are, however, capable of extension in length to 35 mm. Measurements of 100 individuals are given in Table XV. Most of the specimens below 8 mm. in length are immature, and are usually attached to the parent.

TABLE XV

Length and width measurements of 100 specimens of *G. australiensis Goddard.*

Number of Specimens	Length in mm.	Width in mm.	Number of Specimens	Length in mm.	Width in mm.
1	2·5	0·5	1	11·0	5·0
3	3·0	0·5	1	11·5	4·5
4	3·0	1·0	1	12·0	4·0
1	3·5	1·0	1	12·0	5·0
7	4·0	1·0	1	13·0	6·0
2	4·0	1·5	1	14·0	3·0
1	4·5	1·5	1	15·0	5·0
1	4·5	1·5	1	17·0	3·0
1	5·0	1·0	1	17·0	4·0
1	5·0	1·5	1	17·0	5·0
4	5·0	2·0	2	18·0	4·0
1	5·0	2·5	1	18·0	4·5
1	5·5	1·5	2	18·0	5·0
2	5·5	2·0	1	19·0	4·0
9	6·0	2·0	1	19·0	6·0
2	7·0	2·0	1	19·0	7·0
4	7·0	2·5	1	20·0	5·5
3	7·0	3·0	2	20·0	6·0
2	7·5	3·0	1	21·0	5·0
1	8·0	2·5	1	21·0	5·5
3	8·0	3·0	1	22·0	6·0
1	9·0	3·0	1	22·0	7·0
1	9·0	4·0	1	23·0	5·5
1	9·5	3·5	2	23·0	7·0
1	10·0	3·5	1	24·0	6·0
3	11·0	4·0	1	25·0	8·0
5	11·0	4·0	1	26·0	7·0
1	11·0	4·5	1	27·0	7·0
			1	39·0	10·5

Nine specimens carrying young had the following measurements:—

10·0 x 4·0	21·0 x 5·5
17·0 x 5·0	22·0 x 7·0
18·0 x 4·0	27·0 x 7·0
19·0 x 7·0	39·0 x 10·5
20·0 x 5·5	

(*b*) *Shape:* This is typically glossiphoniid.

(*c*) *Annulation:* The external annulation of the body comprises 70 annuli, which are sub-equal in size, except for the smaller anterior ones. Six annuli are incorporated in the anterior sucker, the posterior lip of which is formed by the 7th and 8th annuli, which are fused ventrally.

Eyes are present on annuli 2, 3 and 4. Those of the anterior pair are small and close to the mid-line; those of the 2nd and 3rd pairs are larger and more widely separated transversely, but are close to one another longitudinally.

The reproductive apertures are separated by a single annulus, the 29th. There is one post-anal annulus.

(*d*) *Pigmentation:* The ground colour of the body is light brownish, sometimes having a greenish tinge, especially in larger specimens. There is no conspicuous patterning. Segmental papillae are absent.

Internal Anatomy

(*a*) *Body-wall and Musculature:* The body-wall consists of a cuticle secreted by the one-layered epidermis, the cells of which are columnar. The cuticle and epidermis are raised up into a number of very fine papillae which give the surface a granular appearance in macroscopic view. Among the epidermal cells are goblet-shaped gland cells. These have the same appearance as those described by Goddard for specimens of *G. australiensis* collected in a creek near Oberon, N.S.W., by Dr. Hill.

Beneath the epidermis is a very narrow layer of connective tissue. The narrowness of this layer appears to be a feature in which the Tasmanian specimens differ from those described by Goddard (1908, p. 326) who, in giving an account of the body-wall of the mainland specimens says:

> "The dermis is of considerable thickness, and consists of a matrix in which occur numerous cells with a large nucleus . . . The cells mentioned above as occurring in the matrix constitute the 'excretophores' of other species of *Glossiphonia*."

In the Tasmanian specimens, these "excretophores" have a large, clear secretion space, and their average diameter is 10μ

Beneath the connective tissue layer lies the musculature. The outer layer of circular muscles is 10-15μ thick, while the longitudinal muscles, which are very well-developed, form a layer about 60μ thick. Within the longitudinal muscles is well-developed botryoidal tissue.

(*b*) *Coelom and Vascular System:* The main coelomic elements are the dorsal, ventral and lateral sinuses. Of these, the ventral sinus is the most extensive. In it are found the ventral nervous system, the ventral blood-vessel, the ovaries and the testes. In addition, the ciliated funnels of the excretory system open laterally into the ventral sinus. The dorsal sinus is largely occupied by the dorsal blood-vessel.

These two sinuses are connected segmentally by dorso-ventral connectives. Laterally from these connectives, a branch is given off and passes out to the lateral sinus. This connecting system forms the intermediate lacunae. The lateral sinuses lie among the longitudinal muscles.

(*c*) *Excretory System:* Goddard (1908, p. 336) says:—

> "*Nephridia.*—These are very much reduced and inconspicuous structures. No traces of the nephridial funnels have been seen in section, and no well-marked nephridiopores. The exact number of nephridia I have been unable to determine."

In the specimens before me, nephridia are present in somites IX to XXV. They are large conspicuous structures situated on either side of the alimentary canal, and when fully developed possess two apertures. The external opening on each side is an inconspicuous nephridiopore lying on the ventral surface mid-way between the mid-ventral and lateral positions. The inner opening is a well-developed ciliated funnel. This opens laterally into the ventral sinus at the level of the nerve ganglion, i.e., slightly anterior to the corresponding nephridiopore. This organ has the structure typical for the genus. Not all the nephridia possess this internal ciliated opening, it being absent from somites VII to XIV and XXV. In the lateral expansions of the ventral sinus in which lie the ovaries, the ciliated organs open laterally to these. Since the testes are intersegmental in position, they do not affect the position of the ciliated organs.

(*d*) *Digestive System:* The mouth opening lies about the centre of the anterior sucker, and leads into the proboscis sheath. This contains the proboscis, which extends as far back as XIII/XIV.

The ducts of a number of unicellular salivary glands enter the base of the proboscis, and run longitudinally within it, to open at its anterior extremity. These salivary glands are situated laterally in XI to XVI. They have an average diameter of 100μ. There is a large secretion space filled with finely granular material which stains pink with eosin. The finely granular material is surrounded by the densely granular cytoplasm. The nucleus, which has several nucleoli, is situated within this cytoplasm, and to one side of the secretion space.

The proboscis is followed by a short oesophagus, which in turn leads into the crop. This is a large thin-walled region, normally provided with six pairs of lateral pouches (fig. 52); however, in immature forms, only the posterior five pairs of pouches are present (fig. 51). In such cases the anterior part of the crop canal is wide. The five pairs of pouches which follow arise in somites XVII, XVIII, XIX and XX. The last two pairs, and more especially the last pair, are much longer than the preceding ones. They are directed posteriorly, and the last pair extends back to somite XXVII. This pair is provided with 11 side-branches.

One of the diagnostic features of the genus *Glossiphonia* is the presence of six pairs of crop caeca. Thus at first glance, these specimens having only five pairs of caeca, appear to belong to a different genus. However, the development of the 6th (anterior) pair takes place with age. As the leech grows indications of the presence of the anterior pouches appear, often asymmetrically, so that only one member of the pair may be present in early stages. Large Tasmanian specimens of the leech always have the six pairs of caeca. Goddard noted this feature in specimens of *G. australiensis* from the mainland (1908 *a*, p. 329). In the Lake Dulverton specimens, indications of the 6th pair of caeca may be lacking in individuals of up to 10 mm. in length.

Immediately behind the origin of the last pair of caeca, the canal is constricted off from the following region, the thick-walled intestine. Arising from the main intestinal canal are four pairs of intestinal caeca. These are auriform in shape, and lie in somites XXII, XXIII, XXIV and XXV. The intestinal canal then opens into a large intestinal chamber in XXVI. The entire intestinal region is enveloped in a rich vascular sinus arising from the dorsal blood-vessel. The intestine is succeeded by the rectum, which opens to the exterior at the anus, between annuli 69/70.

Most specimens seen alive have the crop filled with dark material and the intestine with light, a change which is probably due to the processes of digestion.

(*e*) *Reproductive System:* This for the main part agrees with the condition found by Goddard in the mainland specimens. In the male system there are six pairs of testes lying intersegmentally in XV/XVI, XVI/XVII, XVII/XVIII, XVIII/XIX, XIX/XX and XX/XXI, between the crop caeca. The testes are united to paired vasa deferentia which anteriorly become the thick-walled ejaculatory ducts. These are slightly coiled, and extend forward to about XI. Here they turn in a ventro-posterior direction and converge to the mid-line, uniting in XI/XII. The terminal portions of the ducts form the spindle-shaped ejaculatory horns. The system opens at the male pore, which has fleshy lips in XI/XII.

The female organs are a pair of ovaries lying close to the mid-line. They pass anteriorly into oviducts and converge to open by a short vagina at the female aperture.

The species is protandrous. In a specimen 8·5 mm. in length (lacking the anterior pair of crop caeca) the testes are ripe, but the ovaries are very immature. The female ducts from the reproductive aperture to the anterior extension of the ovaries are filled with a mass of connective tissue. This is apparently present until the first eggs are laid.

(*f*) *Nervous System:* The Tasmanian specimens show no difference from the condition described by Goddard (1908, p. 336) for the mainland specimens.

Habits and Relation to the Hosts

G. australiensis is quite active in captivity, moving about the container with a characteristic looping movement. Those with young, when disturbed, roll themselves round their progeny in the typical glossiphoniid manner. When resting normally, the adult leech frequently attaches itself by both suckers and gently undulates the body, probably to ensure efficient aeration of the young attached to the ventral surface.

The members of this species prey on fresh-water snails and are therefore predators rather than parasites.

Comparison with Mainland Specimens

The Tasmanian specimens of *G. australiensis* differ slightly from the mainland type. These differences are chiefly in size, nature of the nephridia, and in the male reproductive aperture.

As shown in table XV there is considerable variation in size, mature specimens being up to four times as large as Goddard's type.

As mentioned above under *Excretory System* the nephridia are well-developed in the Lake Dulverton specimens. In his specimens from N.S.W., Goddard was unable to find any trace of ciliated nephridial funnels. In the Tasmanian specimens these are quite apparent in transverse section, although difficult to distinguish in longitudinal sections.

In the Tasmanian specimens, as contrasted with those of Goddard, the connective tissue layer is very thin.

As regards the genital apertures, Goddard (1908, p. 324) says:—

> "When first examining the species I was inclined to regard the genital apertures as united . . . On making a closer examination with the aid of sections, I found the apertures were distinct but separated by a single annulus—the 29th—which is much diminished in importance. The two apertures open into a depression with tumid lips which lies behind a clitellum-like swelling on the ventral surface between the 28th and 30th annuli. Probably one would be enabled to see these apertures if an examination were made of a perfectly extended organism."

In the larger Tasmanian specimens the male reproductive aperture has thickened lips, and the female aperture is visible as a transverse slit behind the male aperture. In smaller specimens the lips of the male aperture are not so prominent. In no case is the 29th annulus so narrow that the apertures appear to be united.

Distribution

G. australiensis was originally described from specimens collected in a creek near Oberon, N.S.W. (Goddard, 1908). The species was also recorded from Tasmania (?). The specimens described above were collected on 10.3.54, from the underside of stones and pieces of wood in Lake Dulverton, Oatlands.

Sub-family HAEMENTERIINAE

Genus **HAEMENTERIA** de Filippi, 1849

DIAGNOSTIC FEATURES.

Body broadly elliptical to lanceolate. Head region at times expanded and set on a neck-like constriction. Mount-opening always at the front of the sucker, on, or lying immediately behind, the upper lip, never in the centre of the sucker. Usually one pair of eyes, at times two, three or four pairs; rarely without eyes. Normal segment of three rings; in many species a_1 and a_3 are secondarily furrowed ventrally. Dorsum with papillae, which are seldom lacking; many species with pointed tubercles. Proboscis powerful, straight. Salivary glands usually in compact masses. Crop with 7 or 10 pairs of caeca. Reproductive apertures separated by two annuli.

Type: *H.* (*Haementeria*) *ghilianii* de Fillipi, 1849.

Sub-genus **Placobdella**

Species of *Haementeria* having seven pairs of crop caeca and one pair of macroscopically visible eyes, or without eyes.

Type: *H.* (*P.*) *costata* (Fr. Müller, 1846).

A species of *Placobdella* occurs in Tasmania on the lamprey, *Geotria australia* Gray, and appears to be closely related to a species recorded from New Zealand by Benham (*P. maorica* Benham, 1907). The specific name *bdellae* is proposed for the Tasmanian species, in reference to the host animal.

PLACOBDELLA BDELLAE sp. nov.

(Figures 55-61)

DIAGNOSTIC FEATURES

P. bdellae is a small leech, leaf-like in outline. The body is practically colourless and translucent. One pair of macroscopically visibe eyes is present on annuli 3/4. The total number of annuli is 70. There is 1 post-anal annulus. The reproductive apertures are in 27/28 (male) and 29/30 (female). Complete somites are 3-annulate. The salivary glands lie in two groups dorso-lateral to the proboscis in X/XI. Surrounding the region where the oesophagus passes into the crop in XII/XIII are a number of unicellular glands. The seven pairs of crop caeca are lobed distally. Six pairs of testes are present, alternating with the crop caeca in position.

The seminal vesicles and ejaculatory ducts form long loops lying in the ventral lacuna, and extending back to somite XX. Sixteen pairs of nephridia are present. Members of this species parasitize the pouched lamprey *Geotria australis* Gray.

External Features

The body is elongate, broader posteriorly, and somewhat compressed. When the leech is contracted, the shape becomes ovate, broader posteriorly, tapering sharply towards the anterior end. The leeches range in size from 11 mm. x 3 mm. to 15 mm. x 4 mm.

The total number of annuli is 70. Each complete somite is 3-annulate, and the middle (a_2) annulus is slightly larger than the 1st (a_1) and 3rd (a_3). Towards the anterior end of the body, the size of the annuli decreases.

Due to the presence of a large number of papillae, the dorsal surface of the body is rough. These papillae are particularly noticeable on every 3rd annulus (i.e., on the middle annulus of the somite) from the 8th to the 65th and on the 67th and the 69th, where they occur in four distinct longitudinal rows. In the mid-body region a median row is also present. In addition, there are numerous small papillae, which, however, do not form definite rows. The ventral surface of the body is smooth.

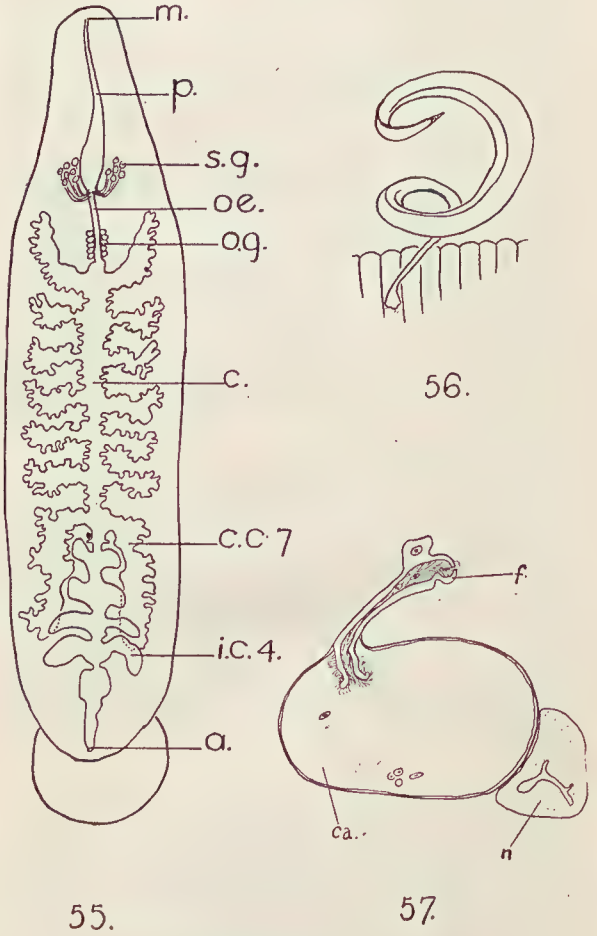
There is one pair of strongly pigmented eyes in somite III (annuli 3/4). They lie close to the midline and are directed antero-laterally.

The male and female reproductive apertures are separated by two annuli, the male opening between 27/28, and the female between 29/30. The anus lies behind the 69th annulus. The annulation of *P. bdellae* and of the closely related *P. maorica* is shown in table XVI.

TABLE XVI

Comparison of the annulation of *P. maorica* Benham and *P. bdellae* sp. nov.

Somite	Nature of Somite	
	P. maorica	*P. bdellae*
I	uniannulate	uniannulate
II	uniannulate	uniannulate
III	uniannulate	biannulate
IV	biannulate	biannulate
V	biannulate	triannulate
VI	triannulate	triannulate
VII-XXIII	triannulate	triannulate
XXIV	triannulate	triannulate
XXV	triannulate	biannulate
XXVI	uniannulate	uniannulate
XXVII	uniannulate	uniannulate
	69 + 2 or 3	70

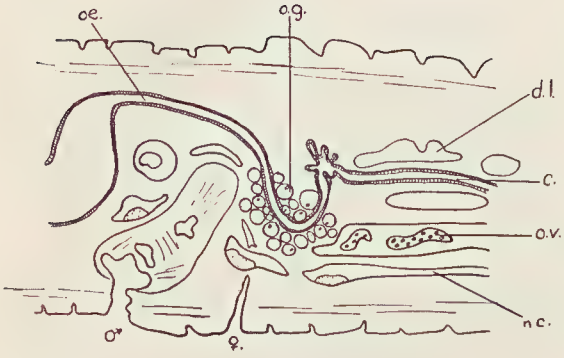


Placobdella bdellae sp. nov.

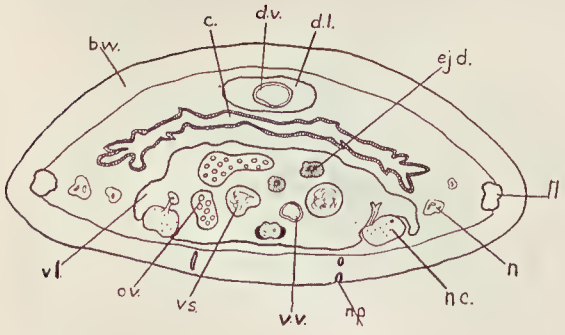
FIG. 55.—Entire animal, showing the alimentary canal.

FIG. 56.—Spermatophore, attached to the body of the leech.

FIG. 57.—Diagram of the nephridial capsule and ciliated funnel. a. anus; c. crop; ca. nephridial capsule; c.c.7, seventh pair of crop caeca; f. ciliated nephridial funnel; i.c.4, fourth pair of intestinal caeca; m. mouth; n. glandular part of nephridium; oe. oesophagus; o.g. glands surrounding the junction of the oesophagus and the crop; p. proboscis; s.g. salivary gland.



58.



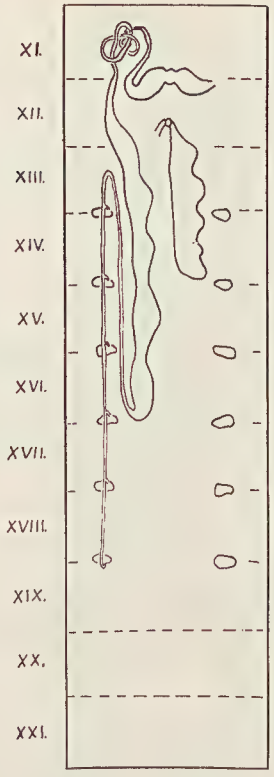
59.

Placobdella bdellae sp. nov.

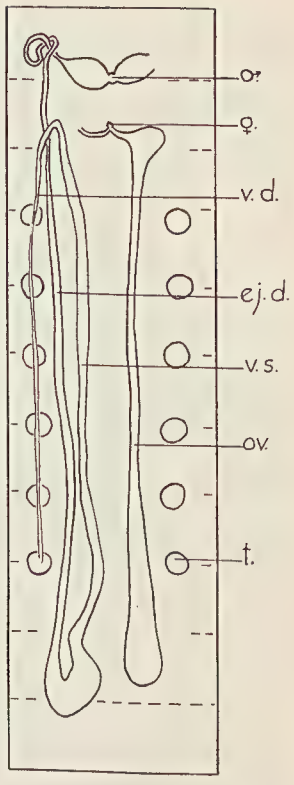
FIG. 58.—Diagrammatic longitudinal section through the median line in the region of the reproductive apertures, showing the glands surrounding the junction of the oesophagus and crop.

FIG. 59.—Diagrammatic transverse section of the mid-body region, showing the position of the main organs.

b.w. body-wall and muscles; c. crop; d.l. dorsal lacuna; d.v. dorsal blood-vessel; ej.d. ejaculatory duct; l.l. lateral lacuna; n. nephridial tubule; n.c. nerve cord; n.p. nephridiopore; oe. oesophagus; o.g. glands surrounding the junction of the oesophagus and crop; ov. ovary; ♂. male reproductive aperture; ♀. female reproductive aperture; v.l. ventral lacuna; v.s. seminal vesicle; v.v. ventral blood-vessel.



60.



61.

Placobdella maorica Benham, 1907, and *P. bdellae* sp. nov.

Comparative diagrams of the reproductive systems.

FIG. 60.—*P. maorica*, after Benham, 1907.

FIG. 61.—*P. bdellae*.

ej.d. ejaculatory duct; ♂. male reproductive aperture; ♀. female reproductive aperture; ov. ovary; t. testis; v.d. vas deferens; v.s. seminal vesicle; XI-XXI. somites XI-XXI.

Internal Anatomy

(*a*) *Body-wall and Musculature:* The outer layers of the body-wall consist of a cuticle and an epidermis. Together these form a layer 15μ in thickness. Beneath the epidermis is a layer of connective tissue, 20μ in thickness. In the middle annulus of each somite the greater part of the connective tissue layer is obliterated by the very well-developed hypodermal lacunae. Beneath the connective tissue layer lies the body musculature, consisting of an outer circular layer, and an inner longitudinal layer. These have thicknesses of 13μ and 100μ respectively.

Inside the musculature is more connective tissue. This is well-developed and as a consequence the coelom is reduced. In the connective tissue layers

surrounding the alimentary canal are numerous fat cells. These have a centrally placed, somewhat lobed nucleus.

(*b*) *Coelom and Vascular System:* The main coelomic elements are the four longitudinal lacunae. These are dorsal, ventral, and the right and left lateral lacunae. Anteriorly the dorsal and ventral lacunae unite in the region of XII, and a single anterior median lacuna is formed. A similar union takes place posteriorly in the anal region. The dorsal lacuna contains the dorsal blood-vessel. In the region of the intestine, this expands and envelopes the intestine and the intestinal caeca as the intestinal sinus. The ventral lacuna contains the ciliated funnels of the nephridia, the central nervous system, the ventral blood-vessel and part of the reproductive system. The ventral blood-vessel lies above the nerve cord. The ovaries and the male reproductive ducts lie in the ventral lacuna, dorso-lateral to the nerve cord. They extend from somite XII to XX. The seminal vesicles and the ejaculatory ducts are dorsal to the ovisacs.

In addition to the four main lacunae, intermediate, segmental and hypodermal lacunae are present.

The intermediate lacunae form an irregular system of coelomic spaces on either side of the alimentary canal. They are particularly well-developed in the posterior body region, where they occupy nearly all the space between the intestine and the body musculature.

The segmental lacunae connect the dorsal, ventral and lateral lacunae. The hypodermal lacunae are given off from the lateral lacunae in the middle annulus of each somite, and extend through the sub-epidermal connective tissue layer on both dorsal and ventral surfaces.

Attached to the walls of the dorsal, ventral and especially the intermediate lacunae are cells which have an average size of 24μ by 15μ. The cytoplasm is alveolar in structure. There is a rounded nucleus, with a single excentrically placed nucleolus. These cells appear to agree in structure and position with the chloragogenous cells described by Scriban and Autrum (1932-34, pp. (8) 188-191), as occurring in various other species.

(*c*) *Excretory System:* The function of excretion is performed by 16 pairs of nephridia. These lie in somites VIII to XXIII. The nephridiopores lie on the ventral surface, mid-way between the mid-ventral and lateral lines. They have a very small vesicle. The nephridial tubules themselves are very well-developed. In longitudinal sections cut slightly medial to the lateral body-wall, the cut ends of the ascending and descending loops occupy a large portion of the lateral body space.

The nephridia, with the exception of those in XI and XII, open into the ventral coelom by large ciliated funnels and capsules. The capsules have an average diameter of 180μ and the funnels a length of about 120μ.

(*d*) *Alimentary Canal:* The mouth lies near the anterior end of the oral sucker in somite II. It leads to the proboscis sheath which contains the thick muscular proboscis. This extends back to XI. The diameter of the proboscis increases posteriorly so that in X it is about twice as wide as it is anteriorly. The posterior end of the proboscis is bent.

Entering the proboscis at its base are the ducts of two groups of unicellular salivary glands. These lie in X/XI, dorso-lateral to the proboscis. The ducts pass back and then forward and down to enter the base of the proboscis in XI. The proboscis opens into the short S-shaped oesophagus, which extends back to XIII. Internally the oesophagus is lined with a thick epithelium. From the base of the proboscis the oesophagus takes an S-shaped course—down and forwards, then up and back—to somite XIII, where it enters the crop.

Surrounding the S-shaped region where the oesophagus passes into the crop are a number of unicellular glands. Their ducts open into the alimentary canal in this region. The glands resemble the salivary glands but their cytoplasm is not alveolar. Similar glands have been described for *P. maorica* Benham (1907), in which species they occur around the anterior part of the crop. In *P. bdellae* the lining of these two regions is very similar, making it difficult to fix the boundary between oesophagus and crop. The glands appear to be oesophageal.

Behind the glandular region, the crop is essentially a straight tube lying dorsal to the ventral lacuna, and extending from XIII to XX. In each of somites XIII to XIX it gives off laterally a pair of diverticula. The anterior pair is directed forwards, and extends into XI/XII. The 2nd to the 6th pairs are directed laterally, and the 7th posteriorly, extending to XXV.

In XX the crop enters the intestine. The anterior part of this bears four pairs of lateral caeca in XX, XXI, XXII and XXIII. Behind the pouched region, the intestine is expanded and somewhat coiled. It passes into a short rectal chamber which opens dorsally at the anus in 69/70.

(*e*) *Reproductive System:* The male reproductive organs consist of six pairs of testes situated intersegmentally in XIII/XIV, to XVIII/XIX. The testes of each side are connected to a longitudinal vas deferens which passes forward to XIII where it turns and becomes expanded to form an elongated seminal vesicle. The seminal vesicle of each side extends back to somite XX, where it turns and becomes once more anteriorly directed. At about somite XVII, the seminal vesicles pass into the ejaculatory ducts. These are of smaller diameter and are lined with a thick glandular epithelium which practically obliterates the lumen of the duct.

Anteriorly the ejaculatory ducts develop muscular walls. They extend forward to X/XI, and then turn back in a postero-ventral direction, as the spindle-shaped ejaculatory horns. These unite in the midline, and the short bursa opens to the exterior by the male pore in XI/XII.

The greatly elongated seminal vesicles and ejaculatoroy ducts are very conspicuous. Throughout their entire length they lie above the ovaries in the ventral lacuna.

The ovisacs are a pair of elongated structures extending from XIII to XX. They are expanded posteriorly and again near the anterior end by masses of ova. From the anterior expansions there is a short oviducal horn or forwardly projecting region on either side. The oviducts are short and unite to form a median vagina which also is short. This passes through the body-wall to open at the female aperture in XII a_2/a_3.

Spermatophores: Two specimens of *P. bdellae* had spermatophores attached to them; the positions were as follows:—

1. dorso-lateral on the right side, slightly anterior to the level of the male reproductive aperture;
2. similar in position, but on the left side of the body.

In *P. bdellae* the spermatophore is about 3 mm. in length. Two-thirds of this consists of the swollen sperm-filled region, and one-third of the narrower stalk leading to the attachment area or pedicel. The two tubes are cemented together for their entire length.

The spermatophores are whitish in colour, so apparently had not long been deposited when the leeches were killed. One spermatophore is straight, the other is coiled.

Habits

The leeches were first observed inside the buccal cavity of a pouched lamprey (*Geotria australis* Gray). This unusual locality did not appear to have any adverse effects on the leeches. Some time later the leeches left the host and were collected whilst crawling freely on the bottom of the aquarium tank in which the lamprey was kept.

The host of the closely related *P. maorica* Benham, 1907, is not known.

Affinities

Up till the present time, about 40 species have been assigned to the sub-genus *Placobdella*. Of these, 11 are doubtful species, and the internal anatomy of a further eight is undescribed. When compared with the remaining species, many of which are inadequately described, *P. bdellae* appears to be most closely related to *P. maorica* Benham, 1907. These two species are the only ones in which the glandular mass surrounding the alimentary canal in XII/XIII has been described.

The chief similarities and differences between the two species are summarised in Table XVII. The other Australian species *P. bancrofti* shows few points of similarity with *P. bdellae* and so is not included in the table.

TABLE XVII

Comparison of *P. maorica Benham* 1907, and *P. bdellae* sp. nov.

Character	*P. maorica* Benham	*P. bdellae* sp. nov.
Size	9 mm. x 4 mm.	11 mm. x 3 mm.—15 mm. x 4 mm.
Number of annuli	70 (7 + 2)	70
Position of mouth	Probably in annulus 2	In somite II
Number and position of eyes	1 pair in annulus 3	1 pair in annulus 3/4
Position of reproductive apertures	Male: 25/26 Female: 27/28	Male: 27/28 Female: 29/30
Position of anus	On annulus 69	Between annuli 69/70
Dorsal papillae	4 longitudinal rows	5 longitudinal rows in the mid-body, 4 elsewhere
Posterior limit of proboscis	IX/X	XI
Salivary glands	Paired lateral masses in XI	Paired dorso-lateral masses in X/XI
Posterior limit of oesophagus	Short	S-shaped, extending to XIII
Crop caeca	7 pairs. The first is directed anteriorly and is sacculated, the 2nd to the 6th are each confined to 1 somite, and the 7th is directed posteriorly through about 4 somites and is also sacculated	7 pairs. The 1st is directed anteriorly, the 2nd to 6th are each confined to 1 somite, and the 7th is directed posteriorly to XXV. All are lobed distally
Anterior glands	Surrounds the crop in XI	Surrounds the alimentary canal in XII/XIII
Intestinal caeca	4 pairs	4 pairs
Ovaries	1 pair, sacculated in XIII/XIV	1 pair, elongated, extending from XIII to XX
Testes	6 pairs, intersegmental in XIII/XIV to XVIII/XIX	6 pairs, intersegmental in XIII/XIV to XVIII/XIX
Male ducts	Vesiculae seminales and ducti ejaculatorii form loops extending posteriorly to XVI	Vesiculae seminales and ducti ejaculatorii form loops extending posteriorly to XX/XXI
Nephridia	Funnels typical; total number not enumerated	16 pairs, in somites VIII/XXIII inclusive; large funnels present in all somites except XI and XII; nephridiopores are absent from XI and XII

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